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Congressional Support for Campaign Finance Reform and Climate Legislation

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CONGRESSIONAL SUPPORT FOR CAMPAIGN FINANCE REFORM AND CLIMATE CHANGE LEGISLATION

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by
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Accepted by:
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Abstract:

This dissertation explores two types of legislation, campaign finance reform and climate change legislation, in order to examine the determinants of congressional voting on these acts. Chapter One outlines a theoretical model based on a model by Denzau and Munger (1986) that predicts that Representatives will vote for campaign finance reform if it improves their campaign contribution position relative to that of their opponents, rather than improves their position absolutely. Empirical estimates show that this is in fact the case and that voting on the 2002 Bipartisan Campaign Reform Act was based on this rather than on party as others had claimed. Chapter Two examines the determinants of the Lieberman-Warner Climate Security Act of 2007. This analysis finds that Senatorial voting for this act was based not on the potential health threats to the Senators states but rather on the cost of the act and the political affiliation of the Senator and his or her constituents. Chapter Three looks at seven economic analyses of Lieberman-Warner Act in more depth. This analysis finds that the economic impacts predicted by these analyses are sensitive to the assumptions made by the researchers. It also finds that many of these studies find that the cost of the Lieberman-Warner Act will be approximately $1,000 per year per household.

Dedication:

This dissertation is dedicated to my loving, supportive and hilarious wife, Alyssa.

Acknowledgments:

This dissertation would not be possible without the knowledge and advice of the faculty of the John E. Walker Department of Economics. In particular, I want to thank my officemate, Ben Compton; co-author, Sergey Mityakov; and the members of my committee, Patrick Warren, Robert Tolison and William Dougan for their help improving the papers in this dissertation.

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Chapter 1

Who Supports Campaign Finance Reform?

Abstract:

The passage of the Bipartisan Campaign Reform Act (BCRA) of 2002 (also known as the McCain-Feingold Act) contains a puzzle. The law was designed to expand the ability of candidates to raise money from individual donors and also crack down on the use of unlimited soft money by the parties. The puzzle is that the bill was voted for largely by Democrats even though the Democrats raised more soft money than their Republican opponents. The explanations offered as to why Democrats would vote for such a bill include ideology and impatience. These explanations are not wholly satisfactory. This paper seeks to explain the apparent contradiction by revising the model of how incumbents raise money for campaigns created by Denzau and Munger (1986) to include contribution limits and the incumbent's ability to set them. The implications of this model are that incumbents compare their own fund-raising abilities to that of their opponents to determine if the law would help their opponent more than it would help them. Using data on campaign contributions from the Federal Election Commission, this paper finds evidence that incumbents did vote in a way that improves their position over their opponents.

Introduction:

The passage of the Bipartisan Campaign Reform Act (BCRA) of 2002 (also known as the McCain-Feingold Act) contains a puzzle. The object of the act was to control so-called "soft money" campaign funding-money donated to the national party committees to avoid the federal limitations placed on donations given directly to candidates. The law raised the limits on hard-money contributions while, at the same time, subjecting the donations to the national parties - which had previously been unregulated - to the same laws as hard money donations. The law would appear to make fundraising more difficult for candidates who relied on soft money for their campaigns; yet, the party that relied most heavily on soft money was the party that voted for its passage. . Republicans in 2000 raised $148 million in soft money while Democrats raised $190 million (La Raja). In terms of hard money, House Republican candidates raised around $273 million dollars while House Democratic candidates raised $264 million dollars (FEC data). While called "bipartisan," the final roll call vote on the BCRA was largely split down party lines. Out of 210 Democrats in the House, 198 voted in favor of the bill; out of 217 Republicans in the House, only 41 voted in favor of the bill.

The McCain-Feingold Act of 2002 was passed after several scandals involving campaign finance came to the forefront of popular attention. Vice President Gore was involved in a high-profile scandal over fundraising activities conducted from the White House (Toronto Star 2000). Claims of corruption also arose when it was discovered that the bankrupt energy trader Enron and many accounting firms had spent over $1.7 million dollars on the campaigns of legislators in the 2000 cycle. While it was never proven that the donations directly induced legislators to defeat bills that would have tightened auditing standards, it did create an appearance of corruption (Washington Post 2002).

These scandals were emblematic of the larger trends in campaign finance that had been occurring throughout the 1990's. Soft money escalated from $86 million in 1994 to $495 million in 2000 (Malbin 2003). Spending on House campaigns increased by 64% in real terms over the period from 1990 to 2004. In 2000 national party committees raised $496 million in soft money, $280 million of which was funneled to the state party committees (La Raja 2001). All told, the local, state and national parties spent $480 million. Much of this money, $160 million, was spent on overhead and administration costs, $65 million was spent on efforts to raise additional money and $229 million was spent on media, mobilization and grassroots campaign activities (La Raja 2000).

The Federal Election Campaign Act of 1974 (FECA) required that all donations made directly to a candidate be subject to rules on declaring the source of the contribution and limiting the amount from certain sources. Individual donors were allowed to give $1,000 directly to a campaign; the party committees and other political action committees were allowed to give $5,000[1] (CFI 2002). If an individual wanted to donate more, he or she had to circumvent FECA-established rules by donating to the parties. Parties were allowed to spend this unregulated "soft money" on party-building activities, voter registration drives and issue advertising. Soft money could be spent on issue advertising because issue advertising did not expressly advocate the election or defeat of a particular

[1] *FECA did not index the contributions to inflation. When enacted in 1974 an individual was able to donate $4,170 in today's dollars.*

candidate. Candidates could raise soft money from donors and have party committees earmark those funds to be used in his or her home state.

Given that Republicans at the time appeared to have the advantage in raising hard money, and the Democrats have a soft money advantage, the perplexing issue is then, why were so many Democrats in favor of the bill when the changes proposed by the BCRA would curtail soft-money contributions?

In the press, many commentators opined that the BCRA would hurt Democrats (Devroy 1989, Lambro 2001). Senator John B. Breaux of Louisiana even changed position on the bill since upon careful examination of the bill he realized it would "hurt the Democratic Party's ability to raise money more than it would hurt the Republicans." (Kuhnhenn 2001) Some commentators suggested that the law was done more for show than for actual reform (Samples 2001).

In academic journals, two explanations are offered. Dennis (1996) looks does empirical work estimating the effect of party, ideology and constituent ideology on Senators' vote for a precursor of the BCRA that never broke the filibuster to make it to a final vote. Dennis finds that liberal ideology, as measured by the score given to Senators by Americans for Democratic, explains why Senators voted as they did. Another explanation for the vote comes from Stephenson (2003). Stephenson notes that Democrats knew that they would be erasing their soft-money advantage with the passage of the bill, but that they also knew the bill would be well perceived in the public eye. For

Stephenson, Democrats rationally traded off soft-money in the future for votes in the up-coming election. Stephenson further estimated that the Democrats must have had a discount rate of higher than 18%.

Rather than rely solely on ideology (Dennis 1996) or extreme time preferences (Stephenson 2003) for an explanation, this paper seeks to explain why certain candidates voted for or against the BCRA based on the characteristics of their fundraising. This paper presents revised version of the model by Denzau and Munger (1986) of campaign finance. The revisions include the addition of contribution limits to the choice of how effort is allocated between possible donors and also set the campaign fundraising process into the incumbent legislator's choice of the limit. The implication of these changes is that incumbents would vote for a change in the limit if it improved their margin of victory. An incumbent will compare her ability to raise certain kinds of funds relative to her opponent's ability and then decide if the new contribution limits improve her situation.

This paper uses data from the Federal Election Commission on various sources of campaign funds to estimate the how changes in the relative fundraising ability of incumbents influence their likelihood of support. Specifically, I use OLS and logit regressions to find the effect of changes in fundraising ability between incumbents and their opponents. The paper also replicates the regressions estimated by Dennis for comparison. The results provide evidence that those incumbents who benefited from increasing their individual donations relative to their opponents were more likely to vote for the bill. Thus, part of the explanation of why Democrats would willingly vote for the McCain-Feingold Act is that it disadvantaged their subsequent challengers relative to themselves.

Bipartisan Campaign Reform Act 2002

Prior to the passage of the BCRA, the laws governing campaign fundraising were set down by the Federal Election Campaign Act of 1971 (FECA). Many of the original provisions of FECA were amended in 1974. One of those amendments created the Federal Election Commission in order to enforce the rules. The main rules governing campaign finance until 2002 were:

- Individual contribution limit of $1,000 per year for each election which in total could not exceed $25,000
- Individual hard-money contribution limit of $20,000 per year to national party committees; $5,000 per year to state party federal committees
- No limit on individual contributions of soft-money to national, state and local committees
- Political Action Committee contribution limit of $5,000 to candidate campaigns or other PACs
- Limits not indexed to CPI to adjust for inflation
- Disclosure rules

Individual donors as well as state and national party committees were limited in the amount of hard money that they could donate to any particular candidate. Hard money was the only allowable source for express advocacy advertising that used specific language like “Elect Smith” or “Defeat Jones.” However, parties were free to spend money on generic party building activities like voter registration, get out the vote and issue ads. Issue advertising was defined as any advertising that did not mention a candidate and only discussed a particular issue like health care. Issue advertising also included advertising which discussed a specific candidate but avoided the language defined by Congress to be expressly advocating a candidate (CFI 2002).

The Act left national and state parties free to spend unlimited amounts of soft money on issue ads, soft money became a larger part of funding for federal elections. Labor unions and corporations were free to donate unlimited amounts of soft money for issue ads (CFI 2002). The two parties total soft-money expenditures steadily increased from $86 million in 1992 to nearly $500 million in 2000 (Magleby 2007). Concerns were growing: unregulated money was increasing the cost of campaigning again and also allowing for the appearance of corruption. In essence, the national and state political parties were able to raise unlimited soft money, of which they could donate limited amounts as hard money to candidates' campaigns and spend as much as they chose on issue ads.

The BCRA aimed to limit soft money expenditures and replace them with regulated, disclosed, hard money instead. BRCA changed the campaign finance laws so that:

- All hard money rules now apply to party committees
- All expenditure on issue ads must be disclosed
- Hard money limits raised

- Individual donations to a candidate $2,000
- Individual donation to a party $25,000

- *Millionaire's Provision*
    - If a candidate self-finances a campaign by more than $150,000 plus $0.04 per eligible voter, then the challenger's hard money limits increase
- Unions and corporations are now prohibited from funding issue ads except when through PAC's
- All amounts are now indexed to inflation by the CPI

A Model of Campaign Finance

The basis of this analysis is the model used by Denzau and Munger (1986). As in their model, candidates are assumed to exert effort in order to raise money to finance their campaigns. This money can come from variety of sources: the candidate, individual donors and political action committees. In my model, it is assumed that all money comes from individual donors. Prior to the next campaign, incumbents choose whether to have a contribution limit (X) and how high to set it. This limit constrains their own donors and their opponent's donors.

The incumbents wish to maximize the difference (D) between their total campaign resources (R) and their opponents'[2] subject to the condition that any constraints must

[2] In reality, it is likely that they will be maximizing their vote share, but the result is largely the same.

apply equally to all candidates. The subscript A denotes the total resources of the incumbent while subscript B denotes total resources of the challenger.

$$D = R_A - R_B \tag{1}$$

The total resources available to the incumbent or the challenger are the sum of all individual contributions. Each donor gives to a candidate in response to how much effort (E) that the candidate has given - or is expected give when elected - to the policies that the donor likes. The total effort that a candidate has is limited, and, thus, the candidate attempts to maximize her total resources subject to the amount of effort with which she is endowed. For notational simplicity, subscripts denoting incumbent and challenger are dropped until later since the maximization process will be the same for both challenger and incumbent.

$$R = R_1(E_1) + R_2(E_2) + \ldots + R_n(E_n) \tag{2}$$

$$E_1 + E_2 + \ldots E_n = E \tag{3}$$

Effort may be thought of as time spent voting or crafting legislation or constituency services. Increasing the effort devoted to one source of contributions will yield more contributions but at a diminishing rate.

$$R_i'(E_i) > 0 \tag{4}$$

$$R_i''(E_i) < 0 \tag{5}$$

Once a contribution limit is in place, a candidate must maximize total resources with respect to the contribution limit, as well as the effort constraint. Contribution limits cap the total donation from a single donor at X.

$$X - R_i(E_i) \leq 0 \tag{6}$$

By the time of the next election, the contribution limit has been set and both incumbents and challengers maximize total campaign resources by allocating effort among various donors subject to the effort limitation and the contribution limit.

$$L = R_1(E_1) + \ldots R_n(E_n) + \lambda_E(E - E_1 \ldots - E_n) + \lambda_1(X - R_1(E_1)) \ldots + \lambda_n(X - R_n(E_n)) \tag{7}$$

The Lagrangian and the Kuhn-Tucker conditions for the maximization problem are:

$$L_i = R_i'(\overline{E}_i) - \overline{\lambda}_E - \lambda_i R_i'(\overline{E}_i) \leq 0 \tag{8}$$

$$\overline{E}_i \geq 0 \tag{9}$$

$$\overline{E}_i\left[R_i'(\overline{E}_i) - \overline{\lambda}_E - \overline{\lambda}_i R_i'(\overline{E}_i)\right] = 0 \tag{10}$$

$$L_{\lambda E} = E - \overline{E}_1 - \overline{E}_2 - \ldots - \overline{E}_n \leq 0 \tag{11}$$

$$\breve{\lambda}_E \geq 0 \tag{12}$$

$$\overline{\lambda}_i \geq 0 \tag{13}$$

$$\overline{\lambda}_E(E - \overline{E}_1 - \overline{E}_2 - \ldots - \overline{E}_n) = 0 \tag{14}$$

$$\overline{\lambda}_i\left[X - R_i(\overline{E}_i)\right] = 0 \tag{15}$$

Condition (9) specifies that all choices of effort must be non-negative. Equation (14) implies that if the effort constraint does not hold-a candidate does not expend all effort-then the shadow cost of effort is zero. Equation (15) implies that if the contribution limit does not hold then the shadow cost of additional contributions from that donor is zero.

Picking a contribution limit that is higher than the amount donated by the highest donor results in equation (16) below.

$$\overline{E}_i\left[R_i'(\overline{E}_i) - \overline{\lambda}_E\right] = 0 \tag{16}$$

$$R_1'(\overline{E}_1) = R_2'(\overline{E}_2) = \ldots = R_n'(\overline{E}_n) = \overline{\lambda}_E \tag{17}$$

Equation (16) specifies that the contributions gained by allocating additional effort to an individual source must be equal to the shadow cost. Putting each of the individual donors together in equation (17) implies that the contribution gained from an additional unit of effort will be the same from all donors.

Since the resource equations are invertible, there is a unique amount of effort that generates the amount of contribution limit, X. Put another way, candidates use $\overline{E}_i$ effort to get X dollars in donations.

$$X = R_i(\overline{E}_i) \tag{18}$$

$$R^{-1}{}_i\left(X\right) = \overline{E}_i \tag{19}$$

When the contribution limits do hold for all of the donors, then the effort limit does not. The shadow cost of additional effort for that donor is zero. This causes equation (15) to reduce to equation (18) where each donor gives X dollars. Candidates devote just enough effort to each source to get the donation of X. The total campaign resources in this case would be the number of donors multiplied by the contribution limit.

The interesting case is when some contribution limits hold while others do not. In this case, Equation 9 results in:

$$R_i'(\overline{E}_i) = \overline{\lambda}_E + \overline{\lambda}_i R_i'(\overline{E}_i) \tag{20}$$

$$\overline{\lambda}_E = R_i'(\overline{E}_i) - \overline{\lambda}_i R_i'(\overline{E}_i) \tag{21}$$

Equation (20) implies that the contribution in response to additional effort will be higher than the shadow cost of effort for constrained donors. Candidates would like to devote additional effort to raising money from these donors; however, the law prevents them from gaining campaign resources in this way so the candidate devotes more effort to unconstrained donors. Equation (21) shows that the shadow cost of effort must be lower when the contribution limits are binding than when they are not.

Once the maximization problem has been solved, the incumbents know how much effort to devote to each donor based on the marginal productivity of effort and the amount of the campaign limit. Incumbents also know how their challengers will react to different contribution limits and, thus, how much they will raise in total.

For simplicity, assume that the incumbent and the challenger have two potential donors (n=2). When X is low enough, both donors are constrained. Since total resources equals the sum of both individual donors both giving X, total campaign resources as a function of the contribution limit are simply:

$$R = X + X = 2X \tag{22}$$

$$E = R^{-1}{}_1(X) + R^{-1}{}_2(X) \tag{23}$$

As the contribution limit increases, the effort constraint gets closer to binding. At some point, X will be such that the effort required to raise 2X is equal to the total amount of effort available. At higher levels of contribution limits, one of the contribution limits will bind and the effort limit will bind.

$$R_1'(\overline{E}_1) - \overline{\lambda}_1 R_1'(\overline{E}_1) = R_2'(\overline{E}_2) = \overline{\lambda}_E \tag{24}$$

$$E - R^{-1}{}_1(X) = E_2 \tag{25}$$

The candidate will devote enough effort to Contributor 1 and allocate the remaining effort to Contributor 2. As the contribution limit increases, the candidate will allocate more effort to the constrained Contributor 1 and less effort to Contributor 2 who will continue to donate less than the limit. Given that there are only two donors in this example, all effort not devoted to the constrained donor goes to the unconstrained donor.

$$R = X + R_2\left[E - R^{-1}{}_1(X)\right] \tag{25}$$

Thus, total campaign resources as a function of the contribution limit can be described by Equation 23.

There is a point at which the contribution limit is high enough that neither donor is constrained, and only the effort limit is binding. Increasing the contribution limit above this point will have no affect on total campaign resources raised.

The choice of X is thus determined in reverse. The incumbent and the challenger determine the optimal amount of effort for each donor as a function of the contribution limit. Then, the incumbent attempts to maximize the difference between her and her opponent's total campaign resources. The subscript A and B are reintroduced here because the resources to both candidates are being compared.

$$D = R_A - R_B \tag{26}$$

$$D = X + R_{A2}\left[E_A - R_{A1}^{-1}(X)\right] - \left[X + R_{B2}\left[E_B - R_{B1}^{-1}(X)\right]\right] \tag{27}$$

$$\frac{dD}{dX} = 1 + \frac{dR_{A2}}{dE_{A1}} * -\frac{dE_{A1}}{dX} - \left[1 + \frac{dR_{B2}}{dE_{B1}} * -\frac{dE_{B1}}{dX}\right] \tag{28}$$

$$\frac{dD}{dX} = -\underbrace{\frac{dR_{A2}}{dE_{A1}}}_{-} * \underbrace{\frac{dE_{A1}}{dX}}_{+} + \underbrace{\frac{dR_{B2}}{dE_{B1}}}_{-} * \underbrace{\frac{dE_{B1}}{dX}}_{+} = 0 \tag{29}$$

Recall equation (19) which shows that the amount of effort needed to achieve a contribution of X is determined by the inverse of the individual donor's contribution response to effort. As X increases more effort goes into the constrained donor. Additional effort in the constrained donor reduces the amount of effort remaining for the unconstrained donor. The first part of equation (29) is positive since increasing X increases the effort it takes to raise X dollars; moreover, increasing X also increases the effort used to raise money from the constrained donor leaving less effort for the remaining unconstrained donor. Thus, equation (29) implies that raising the contribution limit will increase the difference between the incumbent's total campaign resources and the challenger's total campaign resources - if the first half of equation (29) is larger than the second or if the additional campaign resources gained by the incumbent are greater than the recourses gained by her opponent.

That result is simple enough, but it implies that an incumbent will look at two things. How different are her best and next-best donors? And how different are her opponent's best and next-best donors?

Increasing the limit allows an incumbent to raise more money in total, but to receive more money from the most generous donor, she must relinquish money from the other donors. The incumbent knows this happens to her opponent as well. As the contribution limit increases, both candidates allocate effort towards donors that give more in response to additional effort. If the incumbent has two similarly generous donors, then changing the allocation of effort will do little. The gain will be barely larger than the cost. If the incumbent has both a generous donor and a stingy donor, then raising the contribution limit will allow the incumbent to allocate effort away from the stingy donor to the generous donor, losing little and gaining much.

The incumbent will look at how her donors compare and compare that to how her challenger's donors do as well. The level of contributions is not as important as how productive the two candidates are at reallocating effort between their donors relative to each other.

Figure 1 shows the change in total donations as a function of the contribution limit.

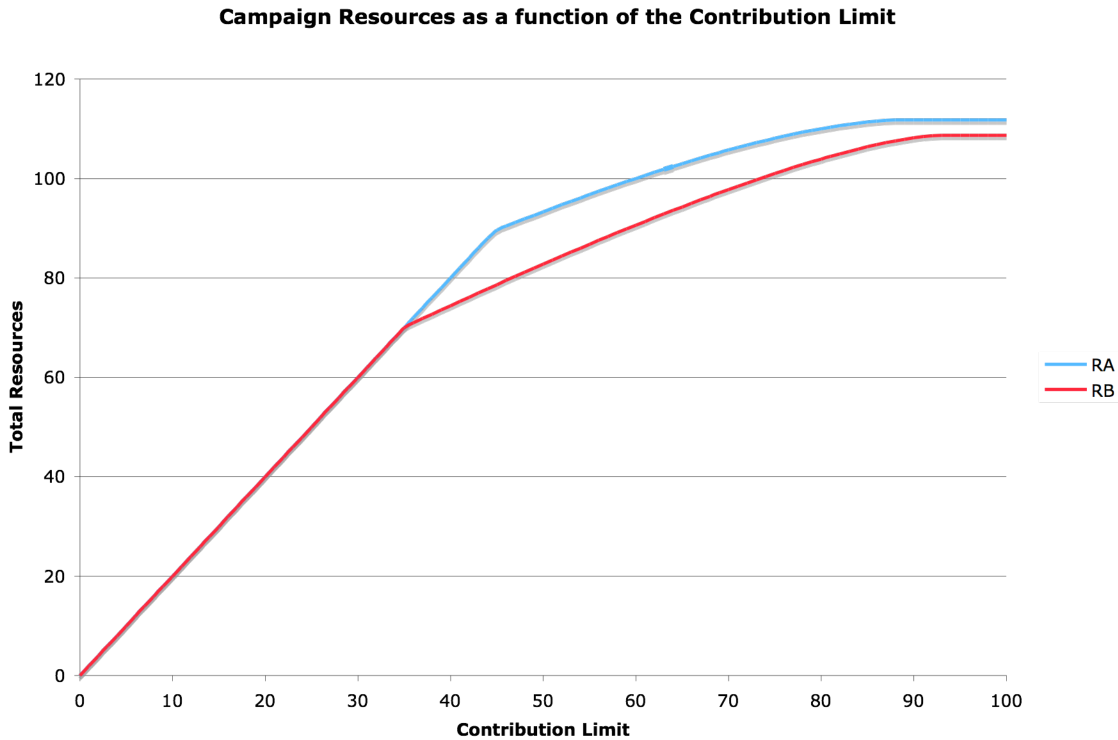


Figure 1

Figure 2 shows the difference between the two candidates' resources. The graph shows that a contribution limit may be preferred to an unconstrained limit. If a candidate favors increasing the campaign limit, it is likely their reallocation of effort will be more productive than their opponents'.

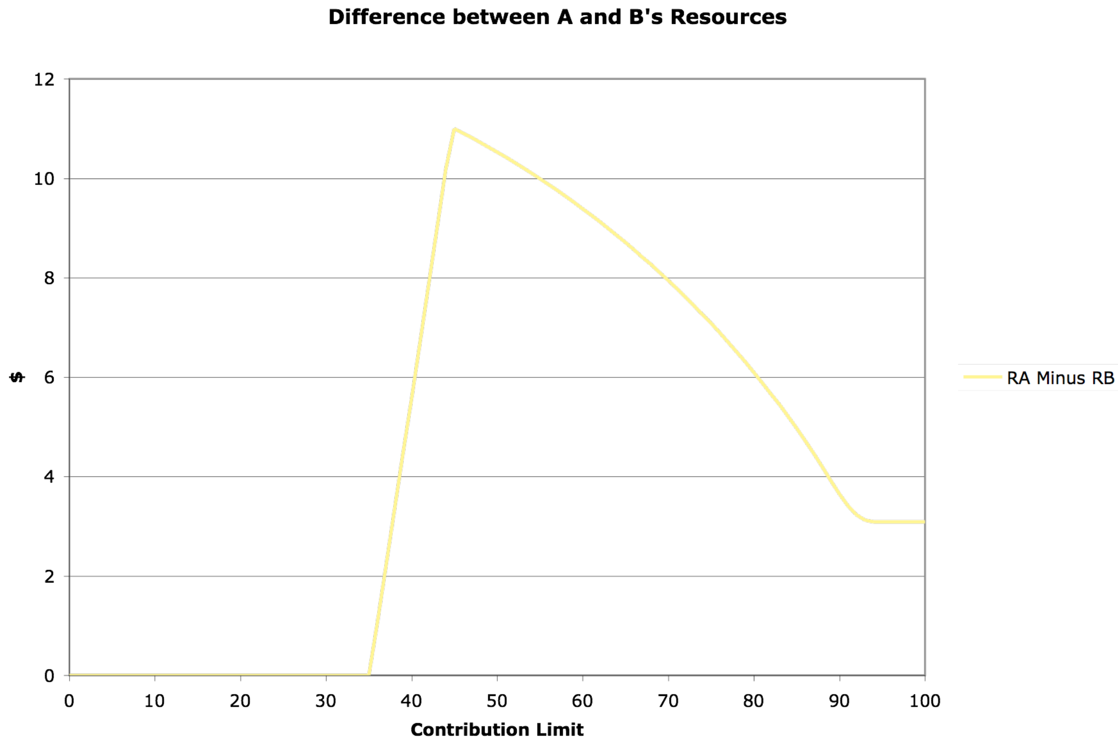


Figure 2

Other Theoretical Explanations:

There are other explanations that have been offered to explain why the Democrats would vote of the BCRA. One explanation claims that differences in ideology explain why Democrats voted for the bill (Dennis 1998). As Dougan and Munger (1989) show, ideology can be a commitment device. Since his estimation was done in 1998, he uses cloture vote in the Senate that would bring the version of the BCRA being considered at the time to a final vote. Dennis uses several variables to capture ideology, which include a party dummy variable, survey data on political beliefs of each state and ADA scores. He also includes dummy variables for if the Senator was up for reelection and the margin of victory by which the Senator won his or her seat. In his regression results, the Senator's ADA score was the only significant variable that affected the vote for the act prompting Dennis to conclude that the vote was cast primarily for ideological reasons.

Another possibility is that the incumbents valued the votes they would receive from their constituencies in the upcoming election more than the soft money they would receive in the future (Stephenson 2003). Stephenson models the approach in what he calls an "issue-based prisoner's dilemma," resulting in a trade-off between votes today and future soft-money. Since the average growth rate in soft money for those incumbents that voted for the BCRA was 18.7%, he reasons that their discount rate must be higher than that. Stephenson does not posit any reasons why in particular Democrats were more impatient that Republicans.

The revised Denzau/Munger model outlined above is an attempt to create a model in which maximizing incumbents with knowledge of the competitors abilities might impose campaign limits in such a way as to better themselves. Thus, the theory should explain the reason behind the apparently contradictory Democrats.

Data: Sources

The data in this paper come from the FEC, which requires all candidates report contribution information by law. The detailed files of the FEC contain information on what person or political action committee donated and when. The site also aggregates the contribution information for each candidate. The data examined in this paper begins in 2000 – the election cycle prior to the law change – and continues into 2004 the first election under the new rules of the BCRA.

From the records of the Clerk of the House, each Representative who voted on the BCRA was followed from the election before the law changes to after the law change. Using FEC reports on the elections, each incumbent who voted on the BCRA was paired with their main party – Republican or Democrat – opponent.

In order to replicate the work of Dennis on the 2002 vote on the BCRA, data on political variables comes from a variety of places. ADA scores come from the Americans for Democratic Action website. Data on the political ideology of each state comes from a survey conducted from 1976 to 1988 as reported by Erikson et. al (1993).

Data: Summary

An examination of the data shows that, on average, total receipts and total campaign spending went up the most for those incumbents who were *against* the BCRA. Non-supporters also, on average, get more money from individual donors. The data on money from labor and corporate PACs seems spilt along party lines. This might lead you to conclude that the supporters voted in favor of a bill that would hurt them while non-supporters voted against a bill that helped them the most. However, as the model above predicts, it is not the levels of these variables that matter, rather how these levels change relative to their opponents.

Empirical Model

The data gathered for this study tests the implications of the revised Denzau/Munger model outline above and contrasts those results with Dennis' specification.

The theory presented above implies that when incumbents set the contribution limit, it is not the level of their contributions that they are concerned with; rather it is the change in their contributions relative to their opponents'. Just because an incumbent raises more money from individual donors does not necessarily imply that the incumbent would want the contribution limit raised. Raising the contribution limit could advantage his opponent more than advantaging himself.

To test the implications of the model, this paper will first look a simple specification. Once enacted, the changes in campaign finance laws made by the BCRA would raise the contribution limit for individual donors. According to the theory, an incumbent will vote for the law change if increasing the contribution limit increases the amount of money the incumbent raises by more than the amount of money her opponent is able to raise.

The theory described earlier implies that these are not the variables that the regression should include. The variables that should be included include change over time and change relative to opponents. To compare the incumbent to the challenger, I create a variable called percent advantage. The percent advantage is calculated as:

$$\frac{R_{2000}^{Inc}}{R_{2000}^{Inc} + R_{2000}^{Chal}}$$

Essentially, the variable measures what percent of the total amount of some type of funding is raised by the incumbent. For example, if the incumbent raised $70,000 in individual contributions and the challenger raised $30,000, then the percent advantage of the incumbent would be 70%. To see how this varies over time, the percent advantage is calculated before and after the law change and the difference is taken.

$$\frac{R^{Inc}_{2004}}{R^{Inc}_{2004} + R^{Chal}_{2004}} - \frac{R^{Inc}_{2000}}{R^{Inc}_{2000} + R^{Chal}_{2000}}$$

Incumbents who were able to increase their lead in comparison to their opponents should be more likely to vote for the BCRA.

The final series of regression are:

> Vote for the BCRA = f (Democratic Dummy, ADA score, General Election Vote Share, General Election Vote Share and Democrat Interaction, Liberalness of Constituency, Change in Percent Advantage in Total Campaign Spending, Change in Percent Advantage in Individual Contributions, Change in Percent Advantage in Corporate Contributions, Change in Percent Advantage in Labor Contributions)

Table 1 reports the results from the initial series of regressions. Because of the process by which percent advantage is created, some observations are unusable. The remaining observations are of Representatives that ran both in 2000 and 2004 and who had opponents who raised enough money to be require filing with the FEC in both periods.

In this specification, relative changes in labor and corporate contributions do not play a large roll in whether a candidate votes for the BCRA. This makes sense as the law did not change the rules regarding how a union or corporation could donate to candidates. The negative sign on the change in total spending is likely due to the fact that if the law improved the position of an incumbent's challenger then the incumbent would have to spend more in response in order to keep her percent advantage constant before and after the law change. If challenger spending is more effective at getting votes than incumbent spending, incumbents would have to increase spending relative to opponents even more causing their percent advantage in spending to increase in order to keep their vote margin the same. There are several studies that estimate the marginal effect on vote share of challenger spending is higher than incumbent spending(Abramowitz 1998, Jacobson 1990, Levitt 1994), but there is not consensus in the literature (Green and Krasno 1988).

The change in percent advantage for individual contributions does change in the expected direction and is significant at the 1% level. For ease of calculation using the OLS results, a 1% increase in percent advantage over his or her opponents leads the incumbent to be .57% increase in the likelihood of voting for the bill. The average Representative saw a 1.7 percentage point increase in percent advantage over her opponents. A Representative that was one standard deviation above the mean saw a 0.27 percentage point increase in percent advantage in individual contributions which translates into 15% increase in the likelihood of voting for the bill.

For comparison, this paper will also replicate the empirical work done by Dennis (1996). In his study, Dennis, uses the cloture vote on an early version of the BCRA in the Senate. This study uses the actual vote in the House, so it benefits from more observations. Because this study focuses on the House, the dummy variable for a reelection campaign in the coming cycle is unusable as Representatives are reelected every two years. Also, to be more easily compared to later estimates, I will use a Representative's general election vote share rather than the margin of victory.

Vote for the BCRA = f (Democratic Dummy, ADA score, General Election Vote Share, Liberalness of Constituency)

The results of this estimate are presented above in Table 1. The results Dennis found are reported in column 1. Column 2 reports the re-estimation of Dennis' results using the data from 2002. Only one of Dennis' original variables was significant and again, in the re-estimation that is true. For Dennis, the Senator's ADA rating was positive and significant at the 1% level. In this study, it is Democratic dummy variable that captures the ideological component. This comparison demonstrates that the results found in Table 1 are not due to the different samples.

Further, the revised Denzau/Munger theory can explain some results that Dennis was unsure of. Dennis mentions in his paper that he is surprised that the closeness of the election as measured by margin of victory was not significant. The theory presented in this paper shows that closeness or safety in the general election has no effect on whether or not a Representative (or Senator) would vote for the BCRA. There is an argument that perhaps Representatives might vote for a bill that while bad for themselves would be good for other members of their party. A Representative's interest in doing such a thing would be responsive to how large their margin of victory is. For this reason, the following estimates will contain the interaction between the general election vote share and party.

The final series of regressions will estimate how the levels different types of campaign contributions affect the likelihood of voting in favor for the BCRA. These regressions will also include the political variables from Dennis's work. This test will form a more traditional analysis in that it includes the levels of campaign spending as well as the political variables used by Dennis. In this way, the following specification will estimate the degree to which the levels, the changes in relative advantage, and political variables affect the likelihood of voting in favor of reform.

> Vote for the BCRA = f (Democratic Dummy, ADA score, General Election Vote Share, General Election Vote Share and Democrat Interaction, Liberalness of Constituency, Total Campaign Spending, Individual Contributions, Corporate Contributions, Labor Contributions)

The results imply that the money raised from individual contributions was not significantly associated with increased likelihood voting for the BCRA. The results from

Column 6 and 7 imply that the battle over the BCRA was between candidates who receive money from labor PACs and corporate PACs. This may simply be due to party as labor mostly donates to Democratic candidates.

The results from Column 6 and 7 show that being a Democrat (and being a Democrat from a safer district) is associated with a higher likelihood of voting for the BCRA. Thus, it would appear Democrats are voting based on ideology with safer Democrats more likely to vote in favor. Those results disappear once the change in percent advantage variables are added; implying that Democratic Representatives were not more likely to vote in favor of the BCRA when their elections were safer.

Conclusion

The story behind the passage of the BCRA illustrates how ideology and self-interest on the part of incumbents guided the vote for campaign finance reform. While the soft money advantage that Democrats had prior to the passage seems to imply that they should be uninterested in voting for the BCRA, this is because there are unobserved characteristics common to groups of incumbents. Democrats, in spite of having lower levels of hard money and higher levels of soft money that Republicans, can benefit from the change in law because the absolute levels are not what the incumbents were using to make their decision. Incumbents looked for a change in contributions relative to their opponents as a factor in determining whether an incumbent was going to vote for the BCRA.

Empirical estimation supports this, finding that if a the law increased an incumbent's share of total individual campaign contributions relative to her opponent by 1 percentage point then the incumbent would be more likely to vote for the BCRA by 0.57%. Ideology was still a large part of why Democrats voted for the BCRA, the changes in hard-money contributions were large enough to potentially sway incumbents who were at the margin. The empirical estimation of this model has other implications; the negative sign on the change in relative advantage in total spending demonstrates that candidates do not like having to spend more money on campaigns even when more money increases the amount they spend relative to their opponents. This may support the theory that additional money spent by challengers is more effective at getting votes than additional

Appendix I:

House of Representative Roll Call Vote on BCRA 2002

	In Favor	Against	Not Voting	Total
Democrats	198	12	5	215
Republicans	41	176	0	217
Independents	1	1	1	3
Total	240	189	6	435

Source: Clerk of the House

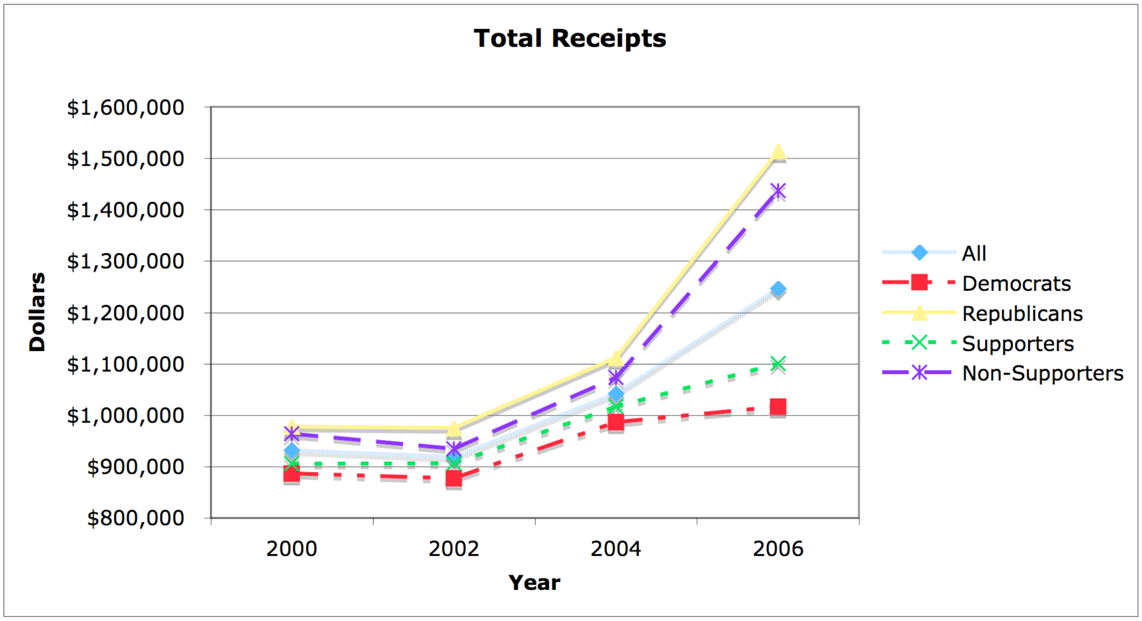
Hard Money Receipts Per Election Cycle (in millions)

Party	1992	1994	1996	1998	2000	2002
Democrat	$199.41	$147.02	$240.79	$169.29	$282.00	$220.24
Republican	$341.42	$271.54	$467.21	$301.92	$467.37	$402.07
Total	$540.83	$418.56	$708.00	$471.21	$749.37	$622.31

Soft Money Receipts Per Election Cycle (in millions)

Party	1992	1994	1996	1998	2000	2002
Democrat	$46.49	$59.66	$140.28	$101.00	$254.00	$245.85
Republican	$63.84	$63.76	$161.86	$144.60	$255.37	$250.03
Total	$110.33	$123.42	$302.14	$245.60	$509.37	$495.88

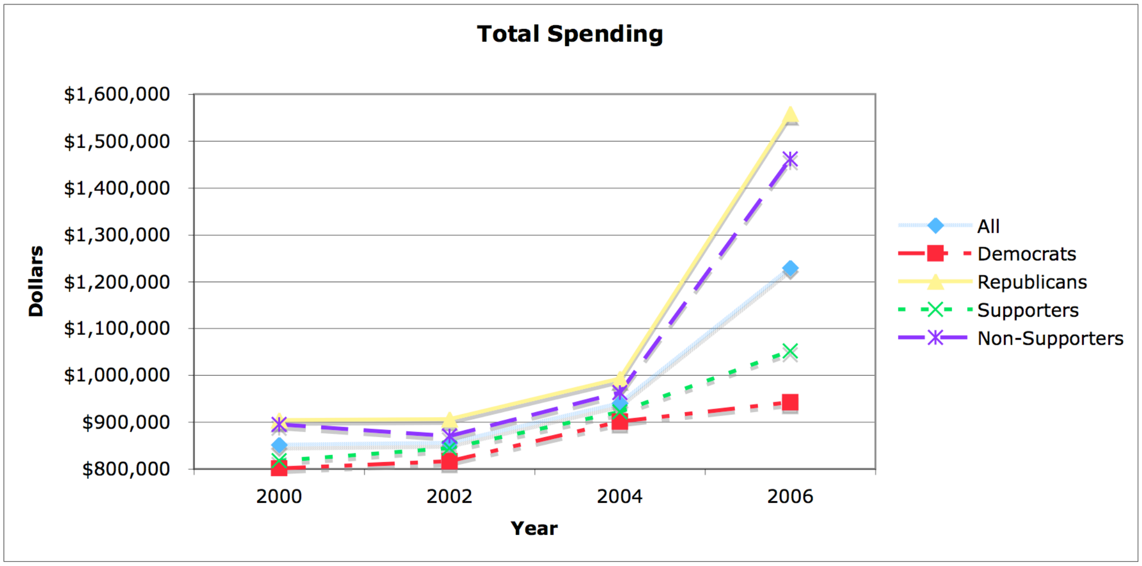
Source: Stephenson 2003



Total Receipts

	2000	2002	2004	2006
All	$931,998	$918,890	$1,042,175	$1,246,768
Democrats	$886,769	$877,047	$986,590	$1,016,492
Republicans	$977,951	$975,445	$1,112,063	$1,514,000
Supporters	$905,865	$906,121	$1,017,156	$1,101,042
Non-Supporters	$964,256	$934,851	$1,073,686	$1,436,846

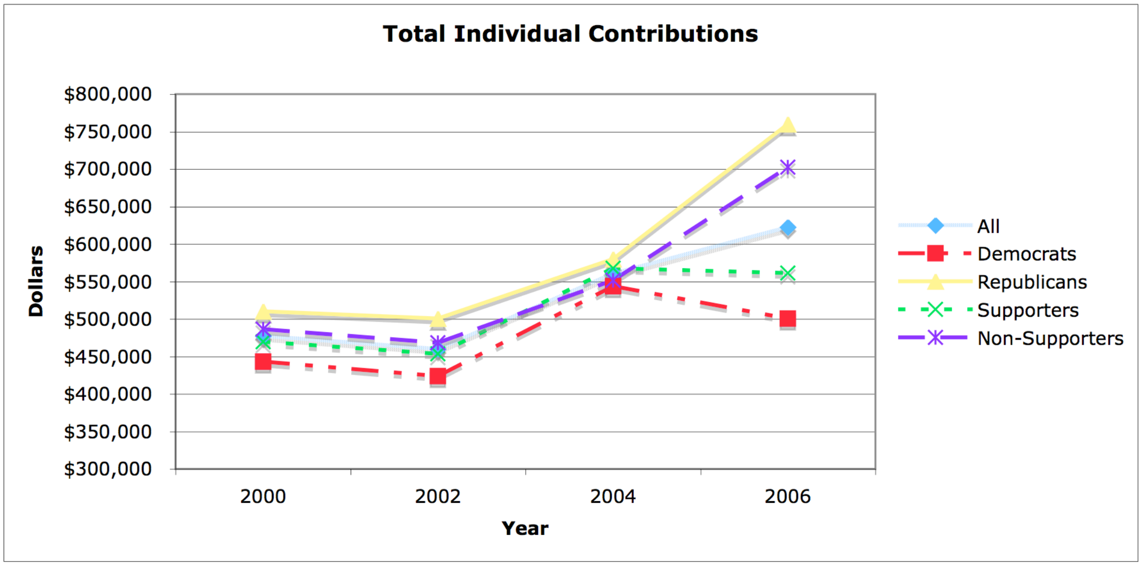
Source: FEC



Total Spending

	2000	2002	2004	2006
All	$851,897	$855,524	$940,025	$1,229,831
Democrats	$801,523	$816,720	$901,651	$942,571
Republicans	$903,858	$906,665	$993,150	$1,558,909
Supporters	$817,219	$844,072	$922,075	$1,052,245
Non-Supporters	$894,704	$869,838	$962,633	$1,461,465

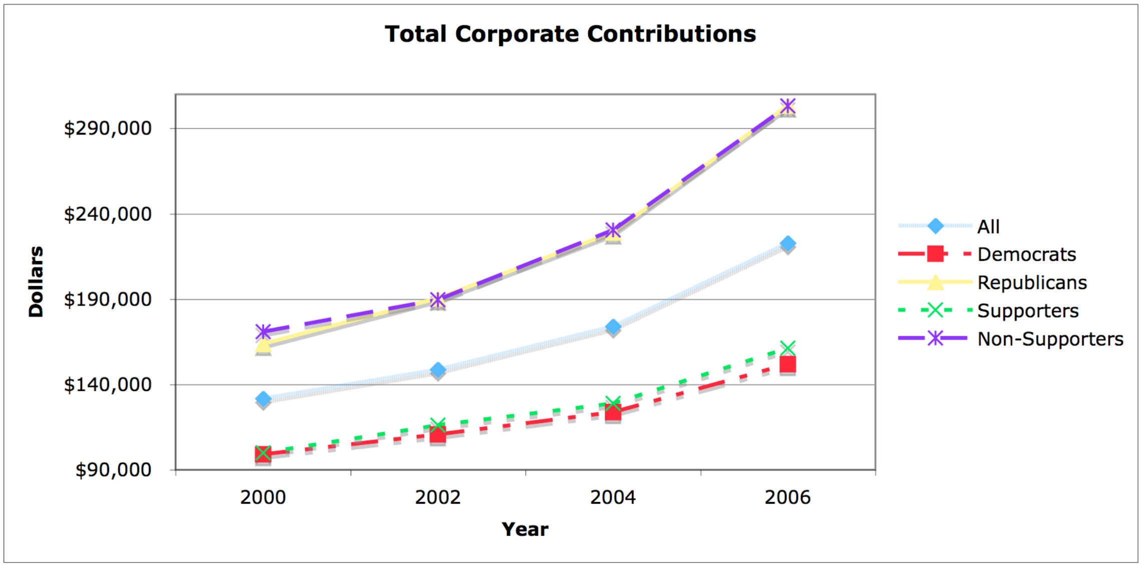
Source: FEC



Total Individual Contributions

	2000	2002	2004	2006
All	$477,421	$459,963	$560,356	$622,591
Democrats	$443,412	$424,059	$544,050	$500,797
Republicans	$510,616	$500,755	$580,183	$760,131
Supporters	$469,847	$453,387	$567,531	$561,303
Non-Supporters	$486,770	$468,183	$551,320	$702,532

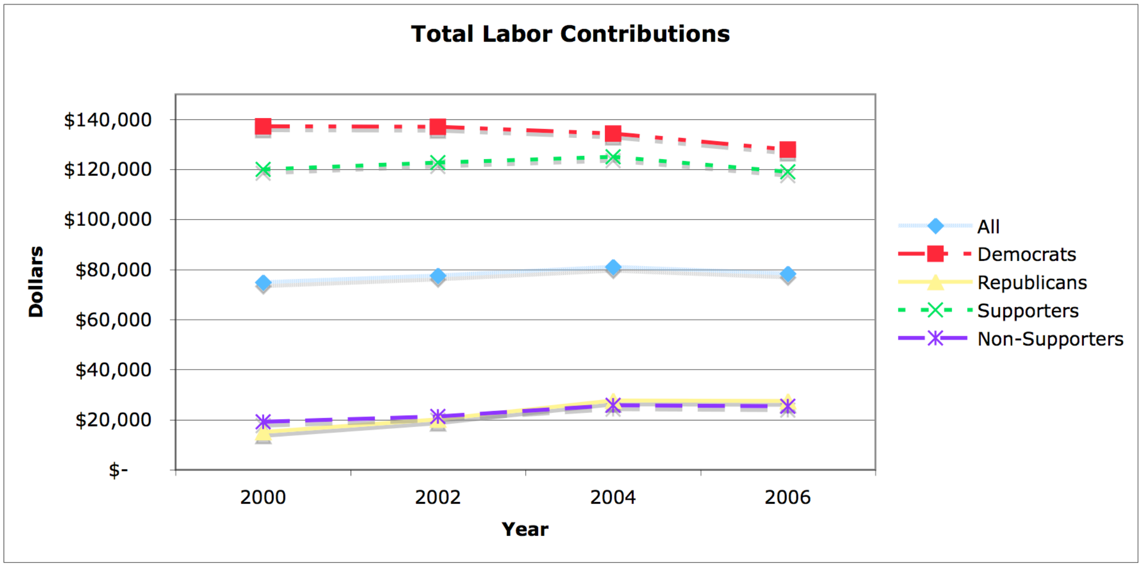
Source: FEC



Total Corporate Contributions

	2000	2002	2004	2006
All	$131,727	$148,791	$173,888	$222,880
Democrats	$98,986	$110,747	$123,785	$151,896
Republicans	$163,859	$190,543	$229,063	$303,362
Supporters	$99,902	$116,207	$128,895	$161,343
Non-Supporters	$171,010	$189,521	$230,556	$303,147

Source: FEC



Total Labor Contributions

	2000	2002	2004	2006
All	$74,873	$77,639	$81,058	$78,435
Democrats	$137,293	$137,010	$134,290	$127,999
Republicans	$15,174	$20,033	$27,632	$27,436
Supporters	$120,078	$122,761	$124,950	$119,082
Non-Supporters	$19,073	$21,236	$25,777	$25,417

Source: FEC

Table 1. Logit and OLS Estimates of Votes Cast for BCRA by House

Group:	House	House
Regression:	Logit	OLS
Independent Variables	**[1]**	**[2]**
Democratic Dummy	7.9604	0.8366 **
	5.1903	0.3708
ADA Score	-0.0013	0.0000
	0.0063	0.0006
Liberalness of Constituency	0.0272	0.0017
	0.0372	0.0028
General Election Percent Vote Share	0.0177	0.0020
	0.0450	0.0051
Interaction Between General Election Percent Vote and Democrat	-0.0445	-0.0014
	0.0748	0.0057
Change in Percent Advantage in Total Spending (in millions)	-7.2080 ***	-0.6226 **
	2.7390	0.2426
Change in Percent Advantage in Individual Contributions (in millions)	7.0292 ***	0.5779 ***
	2.3502	0.2054
Change in Percent Advantage in Corporate Contributions (in millions)	1.6103	0.1029
	1.2265	0.1026
Change in Percent Advantage in Labor Contributions (in millions)	0.0679	0.0309
	0.7441	0.0783
Constant	-2.0071	0.1030
	3.0085	0.3258
Obs	220	220
Psuedo R squared	0.5737	
Ajusted R squared		0.6328

Note: Esimated standard errors are reported below the coefficent estimates (statistically significant at the * .10 level; ** .05 level; **

Table 2. Comparison to Dennis Model

Group:	Senate	House	House
Regression:	Logit	Logit	OLS
Author:	Dennis	Buckley	Buckley
Independent Variables	**[3]**	**[4]**	**[5]**
Democratic Dummy	31.567	4.336 ***	0.759 ***
	3388119	0.578	0.054
ADA Score	0.104 ***	-0.002	0.000
	0.038	0.004	0.000
Liberalness of Constituency	0.150	-0.009	-0.001
	0.203	0.023	0.002
General Election Percent Vote Share		0.000	0.000
		0.012	0.001
Victory Margin	0.052		
	0.058		
Facing Election	-5.214		
	5.162		
Interaction between Facing Election and Liberalness of Constituency	-0.231		
	0.226		
Constant	-1.673	-1.543	0.185 **
	4.302	1.017	0.108
Obs	100	383	383
Psuedo R squared	0.83	0.46	
Ajusted R squared			0.5547

Note: Esimated standard errors are reported below the coefficent estimates (statistically significant at the * .10 level; ** .05 level; *** .01

Source: Column [1] are the estimates reported in Dennis (1998)

Table 3. Robustness Check with Other Specifications

Group:	House	House	House	House
Regression:	Logit	OLS	Logit	OLS
Independent Variables	**[6]**	**[7]**	**[8]**	**[9]**
Democratic Dummy	-3.3210	0.0443	3.1131	0.4060
	2.2478	0.2152	6.5266	0.4247
ADA Score	-0.0015	-0.0002	0.0002	0.0000
	0.0045	0.0005	0.0067	0.0006
Liberalness of Constituency	-0.0237	-0.0012	0.0220	0.0021
	0.0250	0.0022	0.0395	0.0028
General Election Percent Vote Share	-0.0258	-0.0037 *	0.0061	-0.0009
	0.0203	0.0022	0.0553	0.0056
Interaction Between General Election Percent Vote and Democrat	0.0983 ***	0.0083 ***	0.0066	0.0030
	0.0325	0.0028	0.0926	0.0062
Total Spending (in millions)	-0.0122	-0.0143	0.7777	0.0201
	0.6791	0.0586	1.0306	0.0990
Individual Contributions (in millions)	0.4572	0.0420	0.1083	-0.0249
	0.8269	0.0755	1.3195	0.1165
Corporate Contributions (in millions)	-5.5471 ***	-0.5580 ***	-8.2373 **	-0.5909 **
	2.0990	0.2036	3.4503	0.2724
Labor Contributions (in	13.4520 ***	1.0297 ***	15.1094 **	0.7637
	4.2044	0.3876	7.1660	0.5138
Change in Percent Advantage in Total Spending (in millions)			-8.7809 ***	-0.6862 ***
			3.2709	0.2414
Change in Percent Advantage in Individual Contributions (in millions)			8.0567 ***	0.6330 ***
			2.8420	0.2055
Change in Percent Advantage in Corporate Contributions (in millions)			1.1290	0.0148
			1.5903	0.1079
Change in Percent Advantage in Labor Contributions (in millions)			0.2495	0.0207
			0.8174	0.0790
Constant	0.1505	0.4894 ***	-1.3199	0.3820
	1.5392	0.1673	3.8812	0.3779
Obs	382	382	382	382
Psuedo R squared	0.5254		0.6152	
Ajusted R squared		0.5890		0.6273

Note: Esimated standard errors are reported below the coefficent estimates (statistically significant at the * .10 level; ** .05 level; *** .01 level.

Chapter 2

WHO SUPPORTS CLIMATE CHANGE LEGISLATION?

Abstract:

This study is an analysis of the roll call vote on the Lieberman-Warner Climate Security Act of 2008. The Act would create a cap and trade scheme for greenhouse gas emissions. The benefits of this act in terms of avoided health consequences from global warming and the costs in terms of higher energy prices will not be evenly distributed among the states. This paper uses data on the predicted economic and health costs as well as political variables to explain why Senators vote for the Act. The results show that economic costs and ideology are important factors in determining a Senator's vote; however, the potential health costs are not.

Introduction:

The Lieberman-Warner Climate Security Act is one of a variety of legislative methods by which the government can attempt to reduce greenhouse gas emissions for the purpose of mitigating global climate change. The Act could potentially be quite costly, causing the average household to lose an estimated 1% of consumption per year once the policy is in place (Buckley and Mityakov 2009). However, not implementing a policy to curb emissions could be costly in terms of the health impacts of climate change.

This paper seeks to analyze the way that Senators react to potential health threats particular to their states. How the government reacts to future health, environmental, and economic costs is a serious issue for investigation. This study undertakes a positive analysis to determine how Senators react to conditions in their own states. By estimating how much or little Senators respond to certain prospective costs to their constituents, this paper contributes to the considerable literature on the principal-agent relationship between legislators and their electorates.

Proposed legislation addressing climate change generally takes the form of either a carbon tax or a cap and trade scheme. A carbon tax would directly set a price for emissions. Producers who emitted carbon would choose to abate their own emissions to the extent that abatement was cheaper than paying the tax. Raising the tax would lower the total amount of emissions, so the desired quantity of emissions could be achieved by adjusting the tax. Rather than set the price of emitting and letting the market determine the quantity of emissions, a cap-and-trade scheme would set the total quantity of emissions and let the market decide how valuable the right to emit would be. The price of an emission permit would be determined by the costs of abating.

The Lieberman-Warner Climate Security Act of 2007 (S. 2191) was the subject of many studies estimating its effect on the U.S. economy. President Obama, during his campaign, expressed support for a cap-and-trade system targeted to reduce emissions by 80% below 1990 levels (Marshall Institute 2008). In the weeks following his election, the president further expressed his interest in emission abatement by restating his reduction goals in a video message sent to a California climate change conference (Associated Press 2008). Renewed interest in the Lieberman-Warner Act came when the Obama Administration supported a cap-and-trade scheme as a way of generating revenues for the government and addressing climate change simultaneously through a carbon-permit auction that was estimated to bring in from $326 to $853 billion to the government (EIA 2008).

The Lieberman-Warner Act would have created a tradable allowance system for six greenhouse gases - the main gas being CO2. Entities that manufacture fluorinated gasses, petroleum and natural gas, and entities that use more than 5,000 tons of coal per year would be obligated to purchase permits in order to emit these greenhouse gases. The Act limits total emissions to 5,775 million metric tons (mmt) in 2012 and incrementally lowers the amount of total emission permits until 2050. The final reduction in yearly emissions amounts to 80% of the 1990 level. Some of the permits would be auctioned while some would be given to covered entities to cover transition costs and some would be given away as incentives for carbon sequestration (EAI 2008).

By creating a market for tradable emission permits, the government enables the pricing of a previously unpriced asset. Entities that are required to purchase permits will pass part of the cost of these permits to the consumer just as they would in the case of an equivalent carbon tax– even if they are given the permits. The increased price for gasoline, natural gas, electricity and other goods that use these as inputs will cause consumers to face higher prices for many goods relative to the amount of carbon used in their production.

Many scientists warn that if left unchecked global climate change could harm the world economy. A study by Mendelson finds that the United States could lose 0.3% of GDP if the climate rose by 2.5 degrees Celsius while another study by Tol estimates loss of GDP to be 3.4% for only a one degree increase in Celsius (House of Lords 2005).   Scenarios of the consequences of such temperature increases include a greater number of increasingly intense storms, drought, and disease brought on by higher temperatures (Borger 2007).

Senators realize they face a trade-off. Voting for the Lieberman-Warner Act increases the costs of living for their constituents. Not voting for the Lieberman-Warner Act increases the possibility that his or her constituents will be faced with the unpleasant consequences of global climate change. Further, the costs and benefits of the legislation will not be constant across the states. Some states face higher potential costs from seeing energy prices rise and some states would likely see worse consequences than others if the temperature continues to rise.

South Carolina, for instance, is a coastal state and so could see problems due to storms and flooding. South Carolina also has cases arborvirus encephalitis, a mosquito-transmitted disease. If temperatures rise, a greater incidence of the disease could result. These health issues might make South Carolina's Senators more likely to vote for the Act. South Carolina is not well suited for wind, solar or geothermal power generation and only gets 2% of its power consumption from these sources. Thus, South Carolina may be more opposed to a bill like Lieberman-Warner due to the high costs of using these low-carbon, renewable sources. South Carolina, however, does have several nuclear power stations that emit no carbon. South Carolina may be more interested in the Lieberman-Warner Act due to the fact that over 50% of its power comes from nuclear generation. The average household in South Carolina, according to SIAC, is likely to earn $6,000[3] less if Lieberman-Warner passes so Senator's might be wary of being responsible for that loss for their constituents.

This paper uses projections of the state-by-state costs of the Lieberman-Warner Act and state-by-state data on potential hazards from global warming to predict each Senator's decision to vote for the Lieberman-Warner Act. Data on projected household costs of the Lieberman-Warner Act come from a study performed by Science Applications International Corporation (SAIC) on behalf of American Council for Capital Formation

[3] *All dollars values are in 2007 dollars unless otherwise noted.*

(ACCF) and the National Association of Manufacturers (NAM). Data on potential hazards from global warming come from a study by the Institute for Global Risk Research (IGRR) conducted by Janice Longstreth.

Using logit regression techniques, this paper estimates the effect of these potential costs on the likelihood of a Senator voting for the Lieberman-Warner Act. The results show that increasing the potential reduction in household income caused by the Lieberman-Warner Act by $1,000 causes Senators to be 60% less likely to vote for the bill. While Senators react to reduction in household income very strongly, they do not seem to be affected by the potential health consequences from global warming noted by Longstreth.

Lieberman-Warner Climate Security Act of 2007 (S. 2191):

The Lieberman-Warner Act was introduced to the Senate on October 18th, 2007. After being read in the Senate the bill was referred to committees for amendments. On May 20th, 2008 the amended substitute bill from Senator Boxer, S. 3036 was introduced to the Senate. The Senate voted on whether to proceed with the bill as it was, but the motion to proceed required 80% of the vote and only gathered 74%. The bill received amendments that adjusted some of the wording on the United States commitment to preventing climate change and the date that the law would come into effect. On June 6^{th}, the motion to invoke cloture and bring the Act to a final vote failed and the bill returned to the calendar on July 8th. Currently, the Lieberman-Warner Act waits to return to the Senate floor where it can be voted on again (Thomas.gov 2009).

Like Waxman-Markey (?), the Lieberman-Warner Act would have created tradable permit system for the greenhouse gases: CO_2, CH_4, perfluorinated compounds (PFCs) and SF_4. Each of these gases has a different potency, therefore the gases are converted into CO_2-equivalents using based on Global Warming Potential (GWP). The Act limits total emissions to 5,775 million metric tons (mmt) in 2012 and incrementally lowers the amount of total emission permits to 1,732 mmt by 2050. Not all emitters of these gases are required to obtain permits to be allowed to release these gases. Covered entities include upstream petroleum and natural gas producers, manufacturers of F-gases and N_2O and downstream facilities that use more than 5000 tons of coal per year.

To auction the permits the Act established a Carbon Market Efficiency Board. The Board was intended to manage the auction as well as allow covered entities to "bank" permits to use in the future when permits are more scarce. The Board would have auctioned 40% of the permits to covered entities while it retains the leftover permits for other uses (CDA 2008). By 2050 84% of the permits would have been auctioned (EIA 2008). The remaining permits were to be given directly to producers to cover the cost of transition to cleaner technologies and to entities that invest in carbon sequestration. Finally, the Board would have awarded some permits to entities that reduced emissions in non-covered sources; these permits would have covered up to 15% of total allowed emissions. In addition to using permits as incentives, some of the revenues generated by the auction were to be used to fund subsides for cleaner technology research (CRA 2008). Entities might also have purchased permits from comparable foreign cap and trade regimes, which could have been used to cover up to 15% of their total obligation (EIA 2008).

Lieberman-Warner also mandated higher efficiency standards for appliances and building codes. One such standard, the low carbon fuel standard, required all transportation fuel to have an average lifecycle greenhouse gas emission of 10% than the 2008 average by 2020 (CRA 2008).

Literature

The potential health costs that could occur as a result of global climate change are likely to be distributed across the country unevenly. Robert Mendelshon points out that each sector has an “optimal climate,” with some areas being “too cold” and other being “too hot” (Mendelsohn 2005). As such, some areas may look forward to climate change as it could bring them closer to an optimal temperature.

Many scientists focus on the potential costs created by climate change, typically from areas becoming warmer than optimal. Longstreth (1999) does a state-by-state analysis to find what potential health costs there may be due to climate change. In her study, she identifies states that may be threatened in the future by eight different kinds of health consequences. Her study looks at mosquito and rodent-borne diseases, deaths due to heat-related illnesses, heat waves, storms and floods, health hazards from the interaction of heat and pollution, and potential food poisoning from fish contaminated by algal blooms. Instances of these potential health issues are not evenly distributed. Texas, Georgia, Missouri and Louisiana all have six of the eight issues that Longstreth identifies while Alaska, Idaho and Nebraska have none.

Senators are likely to be aware of how much their constituents would suffer from the higher prices brought on by the Lieberman-Warner Act. Since the Act would apply to all states, some costs are going to be borne by people outside of an individual Senator's constituency. The mitigation of climate change has public good attributes in that it is non-rival. This creates a tragedy of the political commons (Laband 2005). Senators would be willing to vote for the Act because the costs are not necessarily borne by their constituents (Maloney et al 1984).

The costs of the Lieberman-Warner Act are not fully internalized. Coastal states, for instance, may be at risk from higher sea levels and would enjoy the benefit of climate change legislation. Land-locked states like Wyoming, would face higher energy prices and gain none of the rewards. Hussain and Laband (2005) find evidence that Senators vote for bills that impose costs in other states than their own. Their study looks at 33 environmental bills from 1991 to 2002 and finds that Senators are significantly less likely to vote for a bill when its costs are internalized by his state.

Data

The voting record of the 110th Congress on comes from the Thomas database. The primary data for this paper comes from two studies. Data on estimated household costs comes from a report by SIAC. Data on projected global warming health costs comes from the IGRR (Longstreth 1999).

The dependent variable in this study is the cloture vote on S. 3036. Since cloture would end the ability of any Senator to filibuster and bring the bill to a final roll-call vote, a vote for cloture is a vote in favor of the bill itself. The use of cloture votes as proxies for final votes is common in other studies of cases in which the bill in question does not make it to a final vote (Dennis 1998). To pass a cloture vote, 60 votes are needed; the Lieberman-Warner Act only received 48 votes. Of those 48, 39 were from Democrats, and 9 were from Republicans.

There are several studies that estimate the effects of the Lieberman-Warner Act (CDA, CRA, CTF, EIA, EPA, MIT). Each study uses assumptions about future technology availability, costs of oil and other natural resources. The SIAC study uses the National Energy Modeling System to estimate how the baseline economy will grow without the Lieberman-Warner Act and then estimates how the economy will grow with the Act.

The NEMS is the modeling system used by the U.S. Energy Information Administration and is used in its Annual Energy Outlook reports to forecast the prices of energy into 2030. The NEMS model calculates how the costs of fossil fuels changes based on the price of permits and other assumed abatement costs. The price changes then affect the demand for these products and the entire economy (EIA 2008).

The SIAC study uses the NEMS model and adds some of its own assumptions about the future costs of abatement technologies, the capital costs of new power plants, and the limitations on the how quickly nuclear, sequestered coal-fired (IGCC) generation, sequestered natural gas-fired (NGCC), biomass and wind energy can be constructed. SIAC uses the EIA's 2007 annual energy outlook to predict fossil fuel prices for the baseline. SIAC also assumes that there is no banking of allowances.

All of these assumptions tend to make the estimates generated in this study higher than comparable studies. The SIAC study estimates that the 2030 price of permit will be anywhere from $227 to $271 in 2007 dollars. The lowest estimated price of an allowance was $49 dollars (CATF 2008) while most other studies examined estimated prices between $60 and $100 (MIT, CRA, CDA, EPA, EIA). The higher estimated costs of permits increase the estimated effect of the Lieberman-Warner Act on energy prices, GDP, employment etc.

SIAC predicts that the average household will earn in income $98,606 under the business as usual scenario in 2014. If the Lieberman-Warner Act passes, SIAC predicts that the average household's income will be $1,010 lower than the baseline scenario. SIAC reports each state's loss using this methodology for 2030. Under the assumptions, SIAC finds that the household in the average state in 2030 will have an income that is around $7,000 lower than it would be if Lieberman-Warner had not been passed. The summary statistics for SIAC's findings are available in Table 1.

The changes mandated by the Lieberman-Warner Act would have increased the price of carbon-intensive energy and caused states to alter their mix of production types based on the new costs. Some states have access to geothermal power based on their geology.

Other states have better access to wind, hydroelectric and solar power based on their geography as well. The data on state electricity generation come from the Energy Information Administration (EIA) and summary statistics are available in Table 1. A Senator's vote is therefore likely to be affected by the presence of these facilities in her state. The use of these facilities in 2007 will proxy the ability to use and expand those facilities in the future if the price of carbon increases rapidly.

The data on public health costs comes from a study by Janice Longstreth with The Institute for Global Risk Research (1999). Longstreth generates information on the states that may suffer disproportionately from global climate change. Rather than use climate models which are still subject to much uncertainty to predict the future this study takes a historical perspective. The paper looks into the prevalence of "summer weather/climate-related diseases" and uses that to determine which regions may be more prone to the problems that climate change may cause.

Longstreth's study analysis three categories of potential health effects: heat-associated mortality and illnesses, temperature aggravated ground-level air pollutants and insect- and animal-borne diseases. The specific variables she identifies are: states with the highest age-adjusted death rates for heat-related illnesses, urban heat-wave impact data and recent experiences with storms or floods, states with ozone non-attainment areas, state history of mosquito-transmitted arborvirus encephalitis, rodent-transmitted hantavirus, and imported cases of malaria or dengue and states with history of algal blooms which cause food poisoning from fish.

Longstreth finds two models of climate change that predict that the death rate from heat-associated illness will double by 2020. As such, the areas that are most at risk from heat-associated illness will be those areas that have issues currently. Urban areas and the South typically see the most age-adjusted deaths from the additional stress placed on the respiratory and cardiovascular systems due to higher temperatures. Heat waves are also an issue in the South and large urban areas. The average annual deaths in the United States from hyperthermia, or heat-related causes, was 688 (CDC 2006). The individual states that have at least one heat-related death per million people in Longstreth's sample are Alabama, Arkansas, Arizona, Georgia, Kansas, Mississippi, Missouri, Oklahoma and South Carolina.

Longstreth also finds a correlation between heat and increases in pollutants such as ozone, carbon monoxide, lead and particulates. Increases in temperature cause the pollutants to be more dangerous leading to more instances of asthma and other illnesses. States that have counties with EPA designated ozone non-attainment areas have a higher risk associated with climate change.

The increases in transmission of certain disease by rodent and mosquito are another potential health cost from global climate change. Cold winter weather reduces mosquito populations thus warmer weather will allow mosquito populations to increase. Longstreth notes that human outbreaks of arborvirus encephalitis are correlated with periods in which the temperature exceeds 85ºF for several days. While the conditions necessary for malaria outbreaks to occur are rare in the United States due to low populations of the disease and use of air-conditioning and screens, resurgence of conditions suitable for malaria and dengue fever do occur in the wake of natural disasters. As for rodent-borne illness, hantavirus, human outbreaks of the disease are correlated with droughts which force rodent populations closer to human dwellings.

Rising temperatures also create disease risks for coastal states. As the surface temperature of the ocean rises, toxin-producing phytoplankton increase in numbers. Shellfish that eat the phytoplankton become contaminated and pass the toxins to humans that eat the shellfish. The largest outbreaks of illness from contaminated shellfish and fish are in the coastal states, however, occasionally, it does affect more inland states when fish is shipped to them.

Storms and floods are predicted to become more frequent and of greater intensity as global climate change continues. Death and property damage are immediate impacts of these sorts of weather events, however death and illness continue in the wake of these events as water is contaminated, power lines are down and disease vectors increase. Longstreth identifies states that have had histories of issues with these events; the summary statistics of which are available in Table 1.

Since all of Longsteth's data are in the form of indicator variables, additional information has been gathered for the present study from the Centers for Disease Control (CDC). Specifically, additional data was found for three of the variables Longstreth identified:

malaria, arborvirus encephalitis, and hantavirus. The CDC reports the number of malaria and hantavirus cases from 2006. Most states report no cases of the disease and in its highest levels there are only 185 cases of malaria and 73 cases of hantavirus. The CDC reports several types of arborvirus, La Crosse, Powassan encephalitis, St Louis encephalitis, and Western and Eastern Equine encephalitis. The reported data on encephalitis cases goes back to 1964 in some cases. Aggregating the number of cases across type and year gives the number of cases over the approximately the last 30 years. Most states have some cases reported and only a few have more than 1,000 cases reported. Summary statistics on the CDC data are available in Table 1.

This paper also includes variables on ideology and lobbying activity to test how the decision to vote for the Lieberman-Warner Act was affected by political factors. To see the effect of ideology, the estimation uses the ratings given by the Americans for Democratic Action. Each of the Senators has been rated from 0 to 100 based on how they voted on 20 bills. To proxy how Senators may be affected by lobbying groups, this paper uses Federal Election Commission data on contributions by the Sierra Club to candidates. Candidates can have money directly spent on their campaign or on behalf of their campaign by the Sierra Club's political action committee. Most Senators did not receive any money from the PAC, however some do receive significant amount with one Senator receiving over $40,000 for a campaign. Since not all of a Senator's actions will be based on his own preferences, this paper will also includes Sierra Club membership as a proxy for a preference for environmental regulation[4]. Summary statistics for the

[4] *I am grateful to Frank Limehouse [and the Sierra Club??] Are these Sierra Club data provided by FL, or did you get some data from each? for this data.*

political variables are available in Table 1.

The state median household income data and population data used to create the percentages mentioned above come from Statemaster.com.

Empirical Estimation

Senators choose to bring any piece of legislation to a vote. A vote in favor of cloture is essentially a vote in favor of the bill. The relative sizes of potential costs and benefits to a senator's constituency affect how likely that senator is to vote in favor. This paper seeks to explain the vote with variables for the health risks the predicted household costs of climate change legislation and ideology.

Health risks will likely cause a senator's to be more in favor of the act. For instance, Storms and floods are predicted to worsen as climate change occurs and given the fact that some of the costs will be borne by other states than the ones receiving the benefits, Senators should be very willing to vote in favor of the bill as a reaction to potential health costs in their state. As Longstreth sees it, states that already have a history of these occurring would potentially see more if the legislation were not passed. The expected sign on any of the potential health hazards proposed by Longstreth should therefore have a positive sign, indicating that the Senator reacted to the presence of those health risks by being more likely to vote for the bill.

The costs to the households will have the opposite effect. Senators in states where there are higher costs will likely vote to protect their constituency from the price increases caused by the legislation. The signs on the coefficients for job loss and household cost are predicted to be negative. Senators will also consider the median income of their constituencies. More affluent constituents will likely be more in favor of the bill if environmental protection has a high income elasticity of demand, as is generally presumed, so the coefficient on this variable is predicted to be positive.

The costs predicted by the SIAC study include estimates of likely costs of construction of new renewable and nuclear facilities as well restricts the amount of new power produced by these facilities to mimic the time it would take to get new facilities operational after the law change. This leaves open the potential that the states will have different laws regulating new nuclear power and different abilities to consume renewable energy. To proxy for these differences, the percent of power generated by nuclear energy and renewable energy are added to the regression. The greater the presence of these facilities already in the state in 2007 should indicate the costs will be lower if the act passes and show the predicted signs on these variables should be positive.

A senator may also be influenced by her own ideology or the ideology of her constituents. The ADA score is added to capture a senator's ideology, although it may also reflect the ideology of the senator's constituency. The more a senator identifies with the Democratic Party the more likely he will vote for this act.

The decision to invoke a final roll call on the amended bill S. 3036 will be a function of, the household costs and other economic variables, the health costs and the Senator's ideology and other political variables.

> Vote in favor of cloture= f (Economic factors, health factors, political factors)

Table 2 shows the results of a logit regression that uses the economic variables, political variables and uses some of Longstreth's health variables, CDC variables. The political variables are all significant at the 10% level or higher. As expected, the higher a senator's ADA score the more likely that senator was to vote in favor of bring S. 3036 to cloture. In fact, a 5-point higher ADA score meant that a senator was 15% more likely to vote in favor of cloture. The negative sign on the amount of contributions from the Sierra Club is an interesting result. It would seem that the Sierra Club does not donate money to people who are already going to vote the way they would like. Rather the Sierra Club donates to the campaigns of senators who are on the fence. A higher donation from the Sierra Club in this case means that the senator was less likely to vote in favor already. These results are consistent with work done by Stratmann (1992). The number of members in the Sierra Club is positive as predicted implying that an increase of 100 members per one million people in the state would increase the likelihood that a senator votes for the Act by 40%.

Of the economic variables that exerted statistically significant impacts on senators' cloture votes, all operated in the predicted direction. Nuclear energy usage in a state implies that the state is already capable of producing energy with low carbon emissions. The sign of the coefficient on renewable energy, however, is negative but insignificant. The cheapest renewable energy sources may already be in use in a state, thus any changes in law that would increase usage of those renewable sources may be expensive and thus a state that heavily relies on renewable power might not be as interested in voting for the act. States with higher median income were more likely to vote in favor of the act, as predicted, but not to a statistically significant extent. The estimated coefficient on household cost is the main result of this paper and was both significant and in the hypothesized direction. An increased loss of household income due to the Lieberman-Warner Act of $1,400 – a one standard deviation increase – leads a senator to be 84% less likely to vote in favor of this act.

The signs on the health variables are largely not as predicted. None of the variables identified by Longstreth had a positive effect on the likelihood of voting for this act. Even when supplemented by data from the CDC, the variables are of the opposite sign and two of which are significant. Other specifications in Table 3 and 4 show similar results; if the results are significant then they are also negative.

Table 4 has uses additional explanatory variables that Longstreth does not identify. There are predictions that sea levels will rise as the planet warms, so coastal states may be more harmed than land-locked states. The coastal variable should be positive, but is not and is not significant. Similarly, global warming may have some affect on skin cancer rates. Again, skin cancer death rates do not predict whether a senator is likely to vote for the Act.

Conclusion

The Lieberman-Warner Act gave senators in high-risk states an opportunity to spread the costs of mitigating climate change to other states. Given this political commons, Senators should be sensitive to the potential health costs from climate change as they will not necessarily have to pay for all of the benefits they will enjoy. However, nearly all of the explanatory power of the model comes from either political or economic variables, implying that Senators are not affected by the potential health threats to their states. In their voting behavior, Senators seem to be demonstrating that a vote in favor of the Lieberman-Warner Act is based more ideological leaning of their constituents rather than the potential harms those constituents face from climate change.

It could be argued that politicians have a high discount factor, and would rather sacrifice tomorrow's environment rather than votes today. However, the household income loss is also incurred in the future. The Act itself would not have begun until 2012 and would likely affect price little until the emission caps started tightening. Politicians are reacting to future economic costs that are themselves uncertain and potentially hard to pin on the Lieberman-Warner Act. It would seem reasonable that if Senators are reacting to one kind of future cost that they would react similarly to other kinds.

The fact that Senators do not react to the potential health affects is perhaps that they favor adaptation to mitigation. The Act would be very costly in terms of lost household income. Senators, in this case, may be attempting to minimize the cost by favoring adaptation to mitigation.

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Appendix II:

Table 1: Summary Statistics

	Variable	Mean	Std. Dev.	Min	Max
Political Variables	Voted for cloture on S. 3036	0.48	0.50	0.00	1.00
	Democrat Indicator	0.49	0.50	0.00	1.00
	ADA Score	55.25	37.41	0.00	100.00
	Amount of Money Donated by Sierra Club to their campaign	$1,758	$5,604	$0	$42,589
	Sierra Club Members as a percent of population	0.23%	0.13%	0.04%	0.61%
Economic Variables	SIAC Job Loss Estimate 2030 (in thousands)	81.06	86.50	8	450.00
	Job Loss as Percent of Current Population	1.4%	0.2%	1.1%	1.8%
	SIAC Household Cost Estimate	$7,383	$1,401	$5,206	$11,701
	Median Household Income 2007	$44,201	$7,294	$31,504	$61,359
	Percent of State Power from Renewable Energy	18%	18%	0%	65%
	Percent of State Power from Nuclear Energy	13%	22%	0%	92%
Health Variables (Longstreth)	Heat-Related Illnesses	0.18	0.39	0	1.00
	Heat Waves	0.18	0.39	0	1.00
	Ozone Non-Attainment Areas	0.60	0.49	0	1.00
	Mosquito-transmitted Arborvirus encephalitis	0.50	0.50	0	1.00
	Hantavirus	0.26	0.44	0	1.00
	Malaria and Dengue Fever	0.64	0.48	0	1.00
	Algal Blooms	0.34	0.48	0	1.00
	Storms and Floods	0.20	0.40	0	1.00
Health Variables (CDC)	Malaria Cases as a percent of population	0.00047%	0.00077%	0%	0.00347%
	Hantavirus Cases as a percent of population	0.00038%	0.00052%	0%	0.00379%
	Arborvirus Cases as a percent of population	0.00008%	0.00013%	0%	0.00073%

Table 2. Logit Regression of Cloture vote for S. 3036 using Longstreth's and CDC's Health Variables

	Independent Variables	[1] Coefficients		[2] Marginal Effects
Political Variables	ADA Score	0.1342	***	0.0296
		0.0407		0.0077
	Contributions from Sierra Club (in thousands)	-0.1420	*	-0.0313
		0.0693		0.0151
	Sierra Club Members per 1 Million People	0.0018	**	0.0004
		0.0009		0.0002
Economic Variables	Percent of State Power from Nuclear Energy	0.0933	*	0.0206
		0.0535		0.0110
	Percent of State Power from Renewable Energy	-0.0109		-0.0024
		0.0370		0.0080
	Median Household Income (in thousands)	0.3171		0.0699
		0.3439		0.0680
	Predicted Household Cost (in thousands)	-2.7243	*	-0.6008
		1.6034		0.3224
Health Variables (Longstreth)	Heat-Related Illness	-2.8221		-0.4021
		2.6900		0.1996
	Heat Waves	-1.0198		-0.1952
		1.6679		0.2819
	Ozone Non-Attainment Areas	-1.3414		-0.3000
		1.8234		0.3755
	Algal Blooms	-0.0674		-0.0148
		1.6087		0.3527
	Storms and Floods	-0.5434		-0.1123
		2.0600		0.3960
Health Variables (CDC)	Hantavirus Cases Per 1 Million People	-0.1982	*	-0.0437
		0.1178		0.0253
	Arborvirus Encephalitis Cases Per 1 Million People	-0.9069	*	-0.2000
		0.5335		0.1244
	Malaria Cases Per 1 Million People	-0.6546		-0.1444
		0.5399		0.0977
	Constant	-1.2176		
		7.9848		
	Obs	100		
	Pseudo R squared	0.7566		

Notes:
Estimated standard errors are reported below the coefficient estimates
Asterisks imply statistically significant at the * .10 level; ** .05 level; *** .01
For indicator variables, marginal effect is calculated as a change from 0 to 1.

Chapter 3

HOW MUCH DOES IT COST TO AVOID CLIMATE CHANGE?

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Abstract:

In this paper we summarize various estimates of the costs of mitigation of adverse impact of the climate change. We find that the differences in the estimated impacts on GDP, consumption, employment, and gasoline, electricity and natural gas prices are mainly driven by the following factors: the timeframe of new technology development, growth potential of existing clean sources of energy, availability of offsets (domestic, international), and banking of allowances.

However, our main finding is that even for more optimistic estimates, the mitigation costs are likely to amount to as much as 1% drop in consumption starting today and going into the future, which, as we argue, constitutes an enormous impact on social welfare. Thus, it is important to carefully assess the costs of global warming to see whether they justify such drastic measures.

Introduction.

Climate change issues have attracted popular interest lately. Given the current evidence from climatology, it seems of little doubt that the climate is getting warmer. There is a growing body of literature which tries to assess the costs of climate change and propose ways to mitigate its negative impacts.[5]

The Democratic and Republican candidates in the 2008 US president election both favored some form of mitigation of the adverse impacts of climate change. The program of the winning candidate Barak Obama supports the implementation of a market-based cap-and-trade system to reduce carbon emissions by the amount scientists say is necessary: 80 percent below 1990 levels by 2050.[6]

It appears likely that some form of cap-and-trade system to cut greenhouse-gases (GHG) emissions will be enacted in the U.S. in the coming years. Thus, we feel it is very important for the public to fully understand both the costs of climate change and the costs of avoiding its negative impacts.

While the media, policymakers, and others have given much attention to the possible negative impacts of the climate change, we feel that comparatively little effort has been devoted to presenting the cost estimates of differing mitigation strategies. American households will bear large costs if any of the proposed plans to curb GHG emissions are adopted.

In the present paper we summarize the available household-level mitigation cost to further facilitate the discussion about the appropriate course of action with respect to global warming. We compare these estimates to gauge their relative sensitivities to differing assumptions. These assumptions include such estimates as the level and timing of proposed abatement efforts, costs and timeframe of developing new, cleaner technologies or improving existing ones, and mitigation efforts on part of other countries, among many others.

In particular, we summarize different cost estimates generated for the Lieberman-Warner Climate Security Act (S.2191) and discuss other legislative proposals such as the Low Carbon Economy Act (S.1766) and carbon tax proposals proffered by

[5] See e.g. IPCC(2007), Stern (2007).
[6] http://www.barackobama.com/pdf/issues/EnvironmentFactSheet.pdf

Representatives Dingell, Stark, and others. Yet our main focus is S. 2191, since its proposed abatement is closer to the positions of current US. Moreover, many have argued a carbon tax system is not a politically viable option for the foreseeable future.

The rest of the paper is organized as follows: Section II compares the results and assumptions of the seven analyses done on Lieberman-Warner Act. Section III discusses S. 2191 in more depth as well as summarizes the individual analyses we investigated. Section IV discusses estimates of other abatement proposals. Section V concludes.

Main Findings

We summarized seven analyses of S.2191 focusing on the cost aspects which we think are of particular importance to American households: change in GDP and resulting change in household consumption, employment changes, and increases in gasoline, natural gas, and electricity prices. The following groups and organizations conducted these studies:

1. MIT Joint Program on the Science and Policy of Global Change
2. The American Council for Capital Formation (ACCF) and the National Association of Manufacturers (NAM)
3. CRA International
4. The Environmental Protection Agency
5. The Energy Information Administration (EIA)
6. The Heritage Foundation's Center for Data Analysis (CDA)
7. The Clean Air Task Force (CATF)

Impact on GDP

GDP cost estimates vary widely from a 0.3%-0.5% to 3% drop in GDP below the business-as-usual in 2015 and from a 1% to 10% drop in 2050. The timeframe of development of new technologies and growth potential of existing clean sources of energy, availability of offsets (domestic, international), and banking of allowances are likely to account for most of these differences in GDP costs estimates.

The studies above make different modeling assumptions about the abatement process; hence, the resulting estimates of GDP losses vary quite a lot. Table 1 shows the estimated impact on GDP from the seven studies under consideration. The MIT group, EIA and CATF predict comparatively lower damage to GDP (around 0.5 % in 2015 and 2030 going up to 1% in 2050); the CRA and ACCF estimates are much higher at 1% on average in 2015 up to 3% in 2030. The CDA and EPA estimates fall somewhere in between these extremes.

A comparative analysis of the results and models' assumptions reveals that the following three factors are likely to account for the differences in the estimated impact on GDP:

- The timeframe of the development of cleaner sources of energy[7] and growth potential of nuclear and renewable sources of energy
- The availability of offsets (domestic, international)
- The banking of Allowances

Table 2 compares the seven models in terms of their assumptions regarding these three factors. Summaries that include more information about the assumptions are available in the Appendix, and Section III provides more detailed information about individual models.

The studies that assume limited availability of alternative sources of energy or slower development and adoption of carbon-free sources of energy predict higher GDP losses. This is quite understandable, since hitting the same abatement target with "dirtier" sources of energy requires greater cutbacks in energy consumption and so results in higher GDP loss. GDP could decrease by a factor of two to three, depending on alternative assumptions.

For example, ACCF/NAM caps some alternative energy source development and deployment such as wind, biomass and clean coal and natural gas carbon capture and sequestration (CCS) technologies. Estimated costs reported by ACCF are higher than for other studies in cases when no such caps are in place. On the other hand, the CATF study using the same NEMS model as ACCF, but without such severe constraints on new mitigation technology development, arrives at much lower GDP loss estimates.

Many other studies include scenarios with different assumptions about alternative

[7] Carbon sequestration and storage (CSS) in particular

energy sources' growth. Different scenarios presuming strong constraints on renewables, nuclear and other forms of cleaner energy development arrive at larger cost estimates. For example, the EPA scenario with constrained nuclear, biomass and carbon capture and storage provides predicts GDP losses which are 1.5 to 2 times higher than the EPA scenarios lacking such technological constraints. Similar effects are observed in other studies as well.

Table 1: Percent Change in GDP from Baseline

Group	Model	Scenario	% Change in GDP from Baseline 2015	% Change in GDP from Baseline 2030	% Change in GDP from Baseline 2050
MIT	EPPA	No Offsets, No CSS Subsidy	-0.65%	-0.31%	-1.10%
		15% Offsets	-0.55%	-0.54%	-0.82%
		CSS Subsidy	-0.66%	-0.26%	-1.01%
		15% Offsets, CSS Subsidy	-0.57%	-0.38%	-0.75%
ACCF/NAM*	NEMS	Low Cost	-0.80%	-2.60%	NA
		High Cost	-1.20%	-2.40%	NA
CRA	MRN-NEEM	S. 2191	-1.75%	-1.00%	-3.50%
CDA*	GI	Generous	-0.14%	-0.56%	NA
		Reasonable	-1.02%	-2.18%	NA
EPA	ADAGE	S. 2191	-0.70%	-0.90%	-2.37%
	IGEM		-2.00%	-3.76%	-6.90%
	ADAGE	S. 2191- No Offsets	NA	NA	NA
	IGEM		-3.30%	-5.90%	-10.10%
	ADAGE	S. 2191- Constrained Nuclear, Biomass and CCS	-1.10%	-2.30%	-4.40%
	IGEM		NA	NA	NA
EAI**	NEMS	S. 2191 Core	-0.30%	-0.30%	NA
		S. 2191 Limited Alternative/ No International Offsets	-0.90%	-0.80%	NA
CATF	NEMS	S. 2191	NA	-0.70%	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020.

Table 2: Assumptions of the Models

Group	Scenario	Limited alternatives	Availability of Offsets	Banking of Allowances
MIT	No Offsets, No CSS Subsidy	Yes	No	Yes
	15% Offsets	Yes	Limited	Yes
	CSS Subsidy	No	No	Yes
	15% Offsets, CSS Subsidy	No	Limited	Yes
ACCF/NAM*	Low Cost	Somewhat limited	Somewhat limited	No
	High Cost	Yes	Limited	No
CRA	S. 2191	No	Yes	Yes
CDA*	Generous	Somewhat limited	Yes	No
	Reasonable	Yes	Yes	No
EPA	S. 2191	No	Yes	Yes
	S. 2191- No Offsets	No	No	Yes
	Constrained Nuclear, Biomass, CCS	Yes	Yes	Yes
EAI**	S. 2191 Core	No	Yes	Yes
	S. 2191 Limited Alternative/No International Offsets	Yes	No	Yes
CATF	S. 2191	No	Yes	Yes

Entities covered by S. 2191 can satisfy their GHG reduction obligations by either purchasing carbon allowances or engaging in other projects which will offset their obligation. Firms can purchase offsets from international cap and trade programs similar to S. 2191 or firms can engage in emission reduction for non-covered emission types, which lowers their obligation on the covered emissions.

This essentially gives firms additional opportunities to satisfy emission caps, and, thus, leads to lower costs of abatement. When no offsets are assumed estimated costs go up in all models by (approximately) a factor of 1.5.

The second major factor affecting mitigation cost estimates is the availability of domestic/international GHG offsets. Entities covered by S. 2191 can satisfy part of their GHG reduction obligations by either purchasing carbon allowances or engaging in other projects offsetting some of their contributions. Firms can purchase offsets from international cap-and-trade programs similar to S. 2191. When no offsets are assumed, estimated costs go up in all the models. Greater availability of offsetting options reduces the economic impacts of Lieberman-Warner. In the EPA model, the absence of international offsets increases estimated costs by a factor of 1.5, from 2% in 2015 to 3% in 2015 (using the IGEM model). ACCF assumes limited amounts of offsets (<20%) in the high cost scenario, which increases estimated cost by a factor of 1.5 compared to the case where there is no such restriction on offsets.

Third factor, which influences estimated costs is availability of "banking" or allowances. This allows enables firms to save unused allowances for later year, essentially enabling firms to gradually adjust their operations to meet targets and lessen the overall abatement costs. When banking is assumed estimated costs fall by a factor of 2.

Finally, the ability to "bank" or store of allowances also has a major impact on the estimated costs of abatement. Allowance banking allows covered entities to save credits they do not use or sell in a given year. Saving credits provides these entities more flexibility when the total number of credits begins to decline in future years. If firms are given the opportunity to store credits, then they can gradually adjust their operations to meet targets and lessen the overall abatement costs. For example, the CRA study estimates costs with and without the banking assumption. When banking is permitted, the entire costs of programs such as those proposed by Lieberman-Warner are decreased.

Studies assuming that no banking of allowances is permitted usually show higher estimates of loss in GDP: for example, the ACCF/NAM, CRA, and CDA scenarios which do not include banking estimate GDP losses 1.5-2 times higher than other models which include banking of allowances, such as the EAI and MIT studies. See Table 2.

Impact on Consumption

Consumption drops are affected by the same factors as GDP costs. As before, studies which assume limited alternative sources of energy and/or limited offsets usually show higher (by a factor of 2 or 3) consumption cost estimates.

However, GDP loss is not the most informative measure of a GHG mitigation plan's household impact. Measuring changes in consumption is a better way of determining each American household's welfare loss. While individual utility/welfare is not directly observable, measuring household consumption is undoubtedly a more direct gauge of household well-being than GDP. Table 2 presents estimated drops in consumption in response to the mitigation path consistent with Lieberman-Warner in 2015, 2030 and 2050.

A comparison of the estimates of Table 2 to those of Table 1, shows the expected pattern: studies that estimate higher drops in GDP are likely to have higher estimated drops in consumption as well. Thus, the assumptions affecting GDP loss (availability of offsets, timeframe of development of carbon free technologies to generate energy, and predictions concerning the growth of nuclear and renewable sources of energy) also alter the magnitude of decreases in consumption.

Studies, which assume limited alternative sources of energy and/or limited offsets, usually show higher consumption cost estimates, as we have seen from examining GDP. The ACCF study, which puts caps on development of nuclear and alternative energy sources, models declines in consumption two to three times higher than the MIT, EPA or EAI studies, which do not make such restrictions. Moreover, an ACCF scenario tightening caps on renewable energy development and limiting offset amounts (the "high cost" scenario) estimates consumption losses increase by a factor of 2.8. When EAI assumes limited alternative to coal and no international offsets, its estimates of consumption losses increases by a factor of 2 to3.

Impact on Social Welfare

Even more optimistic studies predict huge welfare costs in terms of consumption. A lower estimate involves a drop in consumption of 0.8%-1% below the business-as-usual scenario in every year starting in 2008 and going into the future, which represents a huge decrease in social welfare.

The consumption costs estimates permit us also to evaluate the Lieberman-Warner's impact on social welfare. In particular we answer the following questions: How large are the estimated drops in consumption? How can we quantify what a 0.8% decrease in consumption in 2015 or a 3% drop in 2050 means for us today when the abatement decision needs to be taken?

We measure the impact on individual well-being (following Lucas 1990) in terms of balanced growth equivalent. That is, we assume that under the business-as-usual scenario consumption is growing at a constant rate. Mitigation efforts cause consumption to drop below this path. Table 2 contains estimated drops in consumption in 2015, 2030, and 2030. When computing balanced growth equivalent we assume that consumption is growing at the same rate as under business as usual scenario, but its level is permanently below the business as usual path by some percentage. This percentage is chosen so that individual well-being under balanced growth equivalent was the same as under mitigation path. We report this percentage in the Table 2 as well.

Our calculations suggest that consumption under mitigation is equivalent to a constant (in percentage terms) drop in consumption of around 0.8%-1% each year, starting today in 2008 and continuing to 2050.

Table 3: Percent Change in Consumption from Baseline

Group	Scenario	% Change in 2015	% Change in 2030	% Change in 2050	Balanced Growth Equivalent***	Reported Impact
MIT	No Offsets, No CSS Subsidy	-0.35%	-1.93%	-2.36%	-0.96%	Change in Market Consumption
	15% Offsets	-0.29%	-1.60%	-2.10%	-0.81%	
	CSS Subsidy	-0.37%	-1.93%	-2.26%	-0.97%	
	15% Offsets, CSS Subsidy	-0.31%	-1.47%	-2.01%	-0.77%	
ACCF/NAM*	Low Cost	-1.00%	-2.90%	NA	-0.98% (-1.57%)	Change in Household Income
	High Cost	-2.80%	-4.90%	NA	-2.57% (-3.09%)	
CRA		-4.50%	-3.50%	-4.20%	-3.17%	Cost Per Household
CDA*	Generous	-0.60%	-0.48%	NA	-0.41% (-0.42%)	Change in Personal Consumption
	Reasonable	-1.35%	-0.94%	NA	-0.89% (-0.90%)	
EPA**	S2191: ADAGE	-0.43%	-0.91%	-2.10%	-0.65%	Change in Market Consumption
	S.2191: IGEM	-0.66%	-1.44%	-3.26%	-1.02%	
EAI**	S. 2191 Core	-0.40%	-0.50%	NA	-0.31% (-0.36%)	Change in Market Consumption
	S. 2191 Limited Alternatives/No International Offsets	-1.20%	-1.10%	NA	-0.86% (-0.91%)	
CATF	S. 2191	NA	-0.90%	NA	NA	Change in Per Capita GDP

* ACCF/NAM reports in the year 2014.

**EIA reports in the year 2020.

*** Estimates in brackets are computed for studies with “NA” in 2050 on the assumption that damages in 2050 equal to damages in 2030.

At first glance, a consumption decrease of one percent may appear trivial. However, it is worth remembering Nobel Prize winner Robert Lucas estimated the welfare gains from elimination of capital income taxation to be around 1 percent of consumption.[8]

> "…I estimated the overall gain in welfare to be around 1 percent of consumption, or perhaps slightly less. … It is about twice the welfare gain that I have elsewhere estimated would result from eliminating 10 percent points of inflation, and something like 20 times the gain from eliminating post-war sized business fluctuations. It is about 10 times the gain Arnold Harbenger (1954) once estimated from eliminating all product-market monopolies in the U.S."

We estimate that costs of mitigation could be of the same order of magnitude as the welfare effects discussed in the citation above: quite large. In this light it is once again important to assess the costs of global warming to see whether they justify incurring such costs.

Another way to assess these cost figures is to look at the impact of the decrease in consumption on the average American household. Table 4 presents the estimated impact of 1% decrease in consumption for an average household of four people. Projections for business-as-usual scenario consumption are taken from Paltsev et al (2008) study.

Table 4. Impact on Consumption of Average American Household.

	2008*	2015	2030	2050
Population (Million)	301	321	359	397
Consumption (billion 2005$)	$8,217	$11,533	$17,761	$29,567
Consumption/Per capita (2005 $)	27,760	$35,928	$49,474	$74,476
Decrease in consumption per capita (2005 $)	$277	$359	$495	$745
Decrease for a family of 4 (2005 $)	$1,110	$1,437	$1,979	$2,979

*2005 data are used, 2008 are likely to be even higher.

We find that mitigation path is equivalent to a permanent tax increase for the average American household. This increase is projected to amount to an additional $1100 in taxes in 2008. Moreover, this tax is increasing over time in real terms from about $1400-$2000 during 2015-2030 up to $2000-$3000 in 2030-2050.

Average American spends about $2500 on food annually, or approximately $208

[8] See Lucas (1990).

monthly. Decrease in consumption per capita of $277 annually is equivalent, thus, to more than one month without food for the average American, keeping other consumption levels constant.[9]

Another way to gauge this impact would be to compare it to the auto-loan payments. All new 2009 C-Class Mercedes can be leased for $429 per month[10]. A decrease in consumption by $1110 amounts to 2,5 monthly payments on this luxury car, and note that you have to make such payments each and every year and those payments grow in size (it is almost 3,5 monthly payments in 2015 and almost 7 payments in 2050).[11] It is as if you have this luxury car for 2,5 or 7 months out of the year but do not allowed to drive it.

But average American household usually does not buy a Mercedes. What about Honda Civic? All new 2009 Honda Civic LX could be bought for around $189 a month.[12] A decrease in consumption by $1100 equals to almost 6 monthly payments on this car every 12 months (it is 15 monthly payments per year in 2050, i.e. you "buy" more than one car in later years). Again you pay for the car but do not use it.

Thus, we feel that both from scientific and general public point of view the costs of mitigation are likely to be rather high.

Clarifying our Message

Before we move on to discuss other costs estimates we would like to once again clarify our message to avoid the confusion, which is sometimes made in the literature. We find that the costs of mitigation are *equivalent* to a drop in consumption *levels*[13] below the business-as-usual scenario by 1%.

The Natural Resources Defense Council (NRDC) recently published a critical summary of many of the analyses we have examined in this paper.[14] The NRDC

[9] Of course in equilibrium each consumer would change its consumption bundle to avoid being without food. This is just an illustration of the magnitude of the impact.

[10] http://www.carlton.mercedescenter.com/portal/site/DWS72100/menuitem.2bd76a9308ae9c856a916a913aa13453/?vgnextoid=e4407aaeb9a3a110VgnVCM10000014174335RCRD

[11] Note that estimated costs in Table 4 are in real (2005 $) terms. We also make an assumption that Mercedes does not go up in price faster than other goods.

[12] http://www.piedmontcars.net/

[13] We prefer to speak in terms of consumption since this measure allows us to make welfare calculations.

[14] NRDC "Forecasts of the Economic Effects of Climate Change Legislation: What Can We Conclude?" www.nrdc.org/policy

summary suggests that[15] abatement will have only moderate impacts on welfare because cap-and-trade will not stop the growth of US it will just make it slower. The NRDC study also criticizes some of the studies, we surveyed, for suggesting that abatement would involve drops in GDP levels.

We find that the costs of mitigation are *equivalent* to a drop in consumption *levels*[16] below the business-as-usual scenario by 1%. This does not mean that consumption or GDP would actually drop in 2008 by 1%. Most of the costs of mitigation are to be incurred in the future, when abatement targets become tighter. What we mean is that all these future costs are *equivalent* to a permanent drop in consumption by 1% below what it is today and would be have been in the future without the mitigation. That is, under abatement consumer's well-being will be the same as in the case when we cut consumption under no abatement by 1% in every year starting in 2008 and going into the future.

Of course, we could restate the same welfare costs in terms of a lower *growth rate* in consumption/GDP rather than drops in consumption *levels*. These are just alternative ways of measuring the welfare loss. We prefer balanced growth equivalent estimates since they are more standard in macroeconomic calibration exercises.

The fact that GDP does not drop below its 2008 level under the abatement scenario does not mean that the costs of mitigation will be small. The problem is that GDP drops below its *potential* level, the one that would have been attained if mitigation did not take place. Our analysis of available estimates suggests that the welfare costs of mitigation consistent with the provisions of Lieberman and Warner are going to be quite large.

Prices of Carbon Allowances

Estimates of the impact of S. 2191 on employment, the prices of power and fuels

[15] "The most important finding is that, regardless of whether the study is a peer-reviewed academic or government analysis, or a non-peer reviewed industry-backed forecast, one prediction is the same: per capita household income (as measured by per capita gross domestic product, or GDP) will not decrease from today's levels. In fact, all of the projections forecast robust economic growth, despite the limits on global warming pollution contained in the CSA. … The studies do, however, differ in a very crucial way with respect to how they present their results: some give the impression that average household income will decrease from today's level (generally, these are the industry-backed studies), while others are careful to present their estimate more accurately as how much less a household's income is likely to grow as a result of the CSA."

[16] We prefer to speak in terms of consumption since this measure allows us to make welfare calculations.

hinge on the estimated price of carbon allowances. The estimated price of an allowance depends on the availability of banking of permits, the amount of offsets available, the technological development of CCS systems and the number of different GHGs covered.

The estimates of Lieberman-Warner's impact on employment, energy and fuel prices hinge on the estimated price of carbon allowances. The estimated price of these allowances is highly sensitive to several assumptions. Among these assumptions are the availability and extent of banking of allowances, the availability of offsets, the development of CCS systems, and the number of different GHGs covered.

S. 2191 provides for banking of allowances, but the estimates from the CDA and ACCF/NAM do not include banking in their models' assumptions. The CRA, which does including banking, estimates the presence of banking will cause the price of allowances to be higher prior to 2040, but considerably lower afterwards. Thus, in the CRA scenarios, banking reduces the total estimated cost of S. 2191 by $4.7 trillion dollars.

Many analyses test for cost-estimate sensitivity by altering the number of foreign and domestic offsets available at a given time. Lieberman-Warner allows covered entities to use domestic and international offsets for up to 30% of total emissions. The analyses typically restrict the number of offsets in the various cases that they examine. Lowering the number of potentially available offsets increases the price of permits and keeps total emissions closer to the emission path described by the law.

The studies also incorporate varying assumptions vis-à-vis the future feasibility of CCS and the construction of new low carbon power plants. Many authors note that nuclear power is a low-carbon alternative to coal, but regulatory and societal objections present enormous problems for constructing new plants. Other "clean-energy" alternatives like wind and biomass are similarly expected to have potential expansion issues. The analyses also examine costs when CCS technology is either expensive or completely unavailable. Studies by ACCF/NAM and CDA assume alternative power is limited, the EIA and EPA studies test various assumptions about its CCS availability, and studies the MIT and CATF analyses contain no assumptions limiting nuclear, wind or CCS expansion.

Table 5: Carbon Allowance Price (2007$)

Group	Model	Scenario	Carbon Allowance Price 2015	Carbon Allowance Price 2030	Carbon Allowance Price 2050
MIT	EPPA	No Offsets, No CSS Subsidy	$59.15	$106.53	$233.42
		15% Offsets	$50.72	$91.35	$200.17
		CSS Subsidy	$57.91	$104.30	$228.52
		15% Offsets, CSS Subsidy	$50.44	$90.83	$199.03
ACCF/NAM*	NEMS	Low Cost	$36.69	$227.52	NA
		High Cost	$38.36	$271.27	NA
CRA	MRN-NEEM	Banking	$50.00	$90.00	$190.00
		No Banking	$40.00	$80.00	$350.00
CDA	GI	Generous	$50.37	$69.90	NA
		Reasonable	$50.37	$90.46	NA
EPA	ADAGE	S. 2191	$30.55	$64.27	$167.53
	IGEM		$42.14	$87.45	$231.80
	ADAGE	S. 2191- No Offsets	NA	NA	NA
	IGEM		$81.13	$168.58	$447.79
	ADAGE	S. 2191- Constrained Nuclear, Biomass and CCS	$57.95	$118.01	$305.55
	IGEM		NA	NA	NA
EAI**	NEMS	S. 2191 Core	$30.84	$62.71	NA
		S. 2191 Limited Alternative/No International Offsets	$78.12	$160.36	NA
CATF	NEMS	S. 2191	$17.43	$49.03	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020.
Prices converted to 2007$ using CPI

Finally, the MIT study results illustrate that covering other sources of GHGs in addition to carbon dioxide allows reduction in total emissions to be achieved at lower cost. Only the CDA study limits reductions to carbon dioxide instead of the full array of GHGs covered by Lieberman-Warner. This may partially explain why the CDA's predictions are relatively high even when compared to the ACCF/NAM study, which otherwise makes similar assumptions.

Impact on Employment

The assumptions driving the price of carbon allowances also affect the employment estimates. A higher predicted a carbon allowance price gives producers a tighter margin and they are forced to shed jobs to maintain profit levels.

Three of the analyses models changes in employment. The ACCF/NAM, CDA and CRA estimate the net change in employment due to S. 2191. They assume that jobs will be created in new "green" industries like the new power plants incorporating CCS technology. In each of the three cases, the changes in employment correlate with movements in the price of carbon allowances. The ACCF/NAM study shows carbon prices steadily rising as the number of allowances falls over time; as a result, the NEMS model predicts that the net change in employment is negative and increasing. The ACCF/NAM study predicts the loss of 850 million to 1.86 billion jobs in 2014 and up to 3.04 to 4.05 billion jobs lost by 2030. Alternatively, the CDA study predicts an increase in employment of 120 million jobs in 2015 as people are hired in the new "green" industries, under generous assumptions. However, the CDA predicts that more than 500,000 jobs could be lost by 2015. Over the lifetime of Lieberman-Warner, the CDA's estimates predict that job losses will be somewhere between 430,000 and 460,000 in 2030.

The assumptions driving the price of carbon allowances also affect employment estimates. A higher predicted price of a carbon allowance gives producers a tighter margin and they are forced to shed jobs. Both the ACCF/NAM and CDA assume that there is no banking of allowances, while the CRA does assume banking. Banking allows entities covered by S. 2191 to save allowances for future use. Without banking, the price of allowances will start low but rise quickly as the number of available permits falls. Saving drives up the price of allowances in 2015, but it allows the price to be lower than it would be without banking after 2040. In 2015, the CRA estimates that there will be 3.75 million jobs lost. The CRA study models job losses of up to 2.5 and 7.10 million in 2030 and 2050, respectively. Banking might explain why the CRA estimates of job losses are higher than the ACCF/NAM and CDA estimates in 2015. Neither the ACCF/NAM nor the CDA estimate job losses in 2050, but if the banking assumptions influence relative magnitudes of the estimates, then the assumptions behind the ACCF/NAM and CDA analyses would possibly predict more job loss by 2050 than the CRA estimate.

Table 6: Change in Employment from Baseline

Group	Model	Scenario	Change in Employment from Baseline 2015 (millions of jobs)	Change in Employment from Baseline 2030 (millions of jobs)	Change in Employment from Baseline 2050 (millions of jobs)
ACCF/NAM*	NEMS	Low Cost	-0.85	-3.04	NA
		High Cost	-1.86	-4.05	NA
CRA	MRN-NEEM		-3.75	-2.5	-7.1
CDA*	GI	Generous	0.15	-0.46	NA
		Reasonable	-0.717	-0.43	NA

* ACCF/NAM reports in the year 2014.

Impact on Electricity Prices

Table 7 shows the estimated change in the electricity prices from the baseline year. Electricity prices will increase much more than gasoline prices. Lieberman-Warner's cap-and-trade system is estimated to raise the price of electricity by anywhere from 5% to 15% in 2015 and anywhere from 14% in the EPA core scenario to 128% in the ACCF/NAM's high cost scenario in 2030.

The CATF model predicts a 7% increase from the 2005 price in 2030. The EIA, MIT, and ACCF/NAM studies predict a 10%, 37%, and 124% increase in electricity prices from their baseline scenarios to 2030, respectively. By 2050, electricity prices will have leveled off somewhat, returning to near 2015 levels according to the MIT and EPA estimates.

Table 7: Percent Change in Electricity Price from Baseline

Group	Model	Scenario	% Change from Baseline 2015	% Change from Baseline 2030	% Change from Baseline 2030
ACCF/NAM*	NEMS	Low Cost	14.00%	101.00%	NA
		High Cost	15.10%	128.40%	NA
CRA	MRN-NEEM		15.00%	35.00%	60.00%
EAI**	NEMS	S. 2191 Core	5.20%	14.40%	NA
		S. 2191 Limited Alternative/No International	26.90%	67.50%	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020

Impact on Gasoline Prices

Table 8 shows the percent difference between the estimated baseline price and the

S. 2191-estimated price. All models predict that S. 2191 will increase the price of gasoline above the reference scenario price. The CRA predicts that gas prices rise 145% above the reference scenario in 2015, but prices are only 30% in 2030 because the higher CAFE standards are part of the 2030 baseline. The estimates of gas prices show a large range of increases. The lowest estimates are CATF's and EPA's core scenarios increases of 11.6% and 16.7% by 2030, respectively. Alternative scenarios using higher-cost assumptions model increases in the gasoline prices above the reference of anywhere from 41.2% to 145% by 2030.

Table 8a in the Appendix indicates the estimated change in the price of gasoline from the 2005 level. Most models predict that gasoline prices will steadily rise through 2050. In 2015, models that have more generous technology assumptions find that gas prices could be lower than they were in 2005; other models predict gas prices will be up to 25% higher than they were in 2005. By 2030, there is a wide spread in estimates. The CATF study has the lowest estimate of a 5% increase above the 2005 price. The MIT model and the strictest EIA model predicts a 40% to 45% increase while the ACCF/NAM models predicts 66% increase in the generous scenario and a 130% increase in the reasonable scenario. The MIT study, however, estimates that gas prices will hit their highest level in 2030 and return to 2015 levels (which are 20% higher than the 2005 price) by 2050. However, the EPA model predicts that 2050 gas prices will be 66% higher than the 2005 price.

We must note which models incorporate S. 2191's policies on fuel efficiency. Lieberman-Warner requires that all transportation fuels must become 10% less carbon intensive by 2020. The CRA is the only analysis that incorporates this fuel requirement. This provision causes the price of gasoline to increase rapidly in the early part of the forecast; the addition of a stringent fuel-efficiency assumption may be why the CRA's price estimates are higher than the others.

Each model also has a module that estimates the effects of S. 2191 on gasoline prices. The assumptions underpinning these models are rarely specified in the papers but undoubtedly affect the price estimates. Many analyses are not clear in how they model changes in the prices of gasoline. Will gasoline producers simply pass along carbon permit costs to consumers? Only the CATF and EPA models explicitly state they assume the full cost of the carbon permit is ultimately borne by consumers.

Table 8: Percent Change in Gasoline Price from Baseline

Group	Model	Scenario	% Change from Baseline 2015	% Change from Baseline 2030	% Change from Baseline 2050
ACCF/NAM*	NEMS	Low Cost	13.00%	77.00%	NA
		High Cost	50.00%	145.00%	NA
CRA	MRN-NEEM		145.00%	30.00%	82.00%
EAI**	NEMS	S. 2191 Core	9.30%	16.70%	NA
		S. 2191 Limited Alternative/No International Offsets	20.30%	41.20%	NA
CATF	NEMS	S. 2191	9.63%	0.12	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020

Impact on Natural Gas Prices

Table 9 shows the estimated increase in the price of natural gas from the baseline price. Under lower cost assumptions, the models predict that the price of natural gas will be from 12% to 17% higher in 2015 than the baseline cases. In cases with higher costs, natural gas could increases 20% to 49% higher than the baseline estimate in 2015. One thing is certain: any cap-and-trade system will increase the use of natural gas. Natural gas is the best alternative now available to non-CCS coal. If we reduce coal-powered energy generation, we will probably rely heavily on natural gas as a substitute. By 2030, the increased reliance on natural gas will cause the estimated prices to rise 20% to 107% higher than baseline prices in low-cost scenarios and 87% to 145% in the high cost/limited alternatives cases.

Natural gas prices are particularly sensitive to the development of other low-carbon alternatives to existing coal-produced power. The pace and scope of CCS development has massive implications for future natural gas demand. For example, in an ACCF/NAM case assuming limited low-carbon alternatives to coal, natural gas prices rise more than 200% above 2005 levels by 2030. The EIA also predicts increases in the price of natural gas of around 200% in its limited alternative case by 2030. Even the EIA's core scenario predicts natural gas will cost 118% more in 2030. The MIT also predicts that natural gas will be 64% higher than 2005. By 2050, MIT predicts natural gas prices will have declined slightly, but do not return to near the 2015 levels.

Table 9: Percent Change in Natural Gas Price from Baseline

Group	Model	Scenario	% Change from Baseline 2015	% Change from Baseline 2030	% Change from Baseline 2030
ACCF/NAM*	NEMS	Low Cost	17.90%	107.80%	NA
		High Cost	20.70%	145.70%	NA
CRA	MRN-NEEM		12.50%	20.00%	90.00%
EAI**	NEMS	S. 2191 Core	14.20%	26.10%	NA
		S. 2191 Limited Alternative/No International Offsets	49.50%	87.30%	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020

Overall, our results suggests that despite the differing assumptions, the welfare effects of GHG abatement paths consistent with Lieberman-Warner are likely to be huge. Our analysis demonstrates that even under more optimistic assumptions, the costs of abatement consistent with cutting emissions to about 80% below 1990 level, as suggested by the Lieberman-Warner mitigation scenario, are going to be enormous. For this reason, we emphasize that it is important to carefully assess the costs of global warming to see whether they justify similar or more drastic mitigation efforts.

Summaries of the estimates.

Lieberman-Warner Climate Security Act S. 2191 (S. 3036)

We start our review with the Lieberman-Warner Act, which has received considerable attention. It was introduced to the Senate on October 18, 2007. The bill was referred to the Committee on Environment and Public Works and the Subcommittee on Private Sector and Consumer Solutions to Global Warming and Wildlife Protection. These committees held hearings throughout November in which they drafted a substitute bill containing the committees' revisions.

On May 5th, 2008 the amended substitute bill from Senator Boxer, S. 3036, was introduced to the Senate. S. 3036 was under consideration by the Senate on June 6th, but the vote to invoke a final roll call vote on the passage of the bill failed and the bill returned to the Senate calendar on July 8th to be considered again at a later date.

Features of the Lieberman-Warner Climate Security Act (S. 2191)

• Limits total emissions to 5775 million metric tons (mmt) in 2012 and to 1732 mmt in 2050. This amounts to a reduction in the emissions of CO2 and four other global warming pollutants by 4% in 2012, 19% in 2030, and 71% in 2050 below 2005 levels.[17] The targets are stricter for emissions of heat-trapping hydrofluocarbons (HFCs): 15% in 2020, 45% in 2030, and 70% in 2040.[18]

• Creates a tradable allowance system for the CO2, CH4, perfluorinated compounds (PFCs), SF4, and HFCs. Converts non-CO2 gases into CO2-equivalents using Global Warming Potential (GWP). Thus, it covers 86% of total emissions.

• Requires allowances be obtained by upstream petroleum and natural gas producers and manufacturers of HFCs and PFCs (also known as F-gases) and nitrogen dioxide and downstream facilities that use more than 5,000 tons of coal per year.

• Gives away a percentage of allowances that declines over time to cover transition costs to covered entities and manufacturers as incentives for carbon capture and storage (CCS). Auctions the remaining allowances using the revenues to fund low-carbon technology research and development.

• Awards domestic offsets based on carbon capture and the reduction of non-covered emissions, which may be used to cover 15% of obligation. Permits the use of foreign allowances from comparable cap and trade systems to cover 15% of obligations.

• Establishes the Carbon Market Efficiency Board to allow banking of allowances and to potentially adjust the number of allowances created.

Seven Analyses of S.2191

In this section we review and compare seven cost estimates of the Lieberman-Warner's abatement schedule.

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1. Model: Emissions Prediction and Policy Analysis (EPPA)

Group: Massachusetts Institute of Technology (MIT) Joint Program on the Science and Policy of Global Change

Authors: Sergey Paltsev, John M. Reily, Henry D. Jacoby, Angelo C. Gurgel, Gilbert E.

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[17] This amounts to reduction of emissions by 40% below its 1990 levels.
[18] http://www.nrdc.org/legislation/factsheets/leg_07121101A.pdf

Paltsev et al. use MIT's Emissions Prediction and Policy Analysis (EPPA) model to estimate the legislation's effects on total emissions in the United States, the price of energy and the resulting effects on consumer welfare. The MIT study modeled particular provisions in Lieberman-Warner: upstream implementation, inclusions of non-CO2 gases, the crediting of allowances for reducing non-covered emissions, banking of allowances, and the distribution of allowances as incentive to use carbon capture and storage (CCS) technology.

The analysis tests various stringency assumptions by changing the amount of offsets available and the effect of a government subsidy for CCS. It specifically does not estimate how S. 2191 interacts with other mandates for reducing emissions (for instance H.R. 6), the effects of mixing of free distribution and auctioning of allowances, or the Federal Carbon Market Efficiency Board.

The MIT study presents a baseline scenario and four other scenarios. The strictest scenario does not allow any offsets nor include the subsidy for CCS technology. The second scenario relaxes the offset restriction to cover up to 15% of emissions. They assume that foreign offsets are too costly to be feasible. The third scenario returns offset availability to zero and adds the CCS subsidy. The final scenario allows both 15% offsets and the CCS subsidy. This scenario is actually the closest to the actual provisions of Lieberman-Warner.

Under the assumptions mentioned above, the paper finds that price of an allowance will rise steadily over time as total emissions levels fall from 5775 mmt in 2012 to 1732 mmt in 2050. Allowance costs range from $47 to $56 under their strictest assumptions in 2015 and rise to $188 to $221 by 2030.[19]

The EPPA model predicts GDP in 2015 will be 0.65% lower than baseline GDP in the strictest scenario and 0.57% lower in the more relaxed case. By 2050, GDP is estimated to be 1.1% to 0.75% lower in the strictest and least strict cases.

The economy-wide amount of spending on consumption falls due to price increases. The model predicts that consumption could fall from 0.29% to 0.37% in 2015 and 2.01% to 2.36% in 2050. Paltsev et al. use equivalent variation to measure the

[19] All dollar values are denominated in 2005 dollars.

effects on consumer welfare; essentially, equivalent variation gauges how much a person would pay to avoid an increase in prices. The model predicts that welfare loss would be 0.7% in 2015 in both the cases and would be 1.81% and 1.54% in 2050. Stated another way, consumers would be willing to pay $9.7 billion to avoid the price increases that S. 2191 creates in 2015 and they would be willing to pay $554.2 billion to avoid the price increase in 2050 for the least strict model.

The paper also estimates that by 2050, the prices of petroleum products will increase by around 22%, natural gas by around 82% and electricity by around 61% from 2005 levels.

2. Model: National Energy Modeling System (NEMS)

Group: American Council for Capital Formation (ACCF) and National Association of Manufacturers (NAM)

Authors: Science Applications International Corporation (SAIC)

The analysis in this paper was conducted by SAIC based on the assumptions and information provided by ACCF and NAM. The paper uses the National Energy Modeling System (NEMS) to estimate the effect of S. 2191 on national economic indicators, energy production and energy prices. The estimate includes the effect of H.R. 6[20] as well as updated construction costs for power generating facilities.

The ACCF and NAM assume two different scenarios, which they call "low cost" and "high cost." Under the low-cost scenario, offsets are available for more than 20% of emissions, oil prices are set based on the Annual Energy Outlook (AEO) 2008, and there are built-in constraints for each kind of power generation. The high-cost scenario constrains available offsets to be between 15% and 20%, uses *AEO 2007* High Profile Side case for the price of oil and has tighter caps on building. Neither scenario accounts for any banking of allowances.

Under these assumptions, SAIC finds that carbon allowance prices will rise from $36.69[21] in 2014 to $271.27 in 2030.[22] GDP decreases as the allowance prices rise over

[20] H. R. 6 increases higher CAFE standards to 35 mpg and sets the minimum mpg at 27.5. The bill also increases production of renewable fuels from 4 billion to 36 billion gallons and increases efficiency standards on certain household appliances, light bulbs and electric motors.

[21] All dollar amounts denominated in 2007 dollars.

[22] These estimates of the price (and all resulting effects on GDP and prices of energy) are sensitive to the assumption that there is no banking of allowances. A study conducted by CRA International tested the

the period of the forecast. In 2014, GDP is 0.8% lower than the baseline in the low cost scenario and 1.6% lower in the high cost scenario. By 2030, GDP is 2.6% and 2.7% lower than the baseline in the low cost and high cost scenarios respectively. Due to higher production costs, the net job loss attributed to S. 2191 would range from 0.85 million jobs to 1.86 million jobs in 2014 and 3.04 million jobs to 4.05 million jobs in 2030.

The model estimates that the loss to the average household income would be 1.0% to 2.8% in 2014 to 2.9% to 4.9% in 2030. The paper also estimates that the residential price of electricity will rise by about 13% above the baseline in 2014 and between 101% and 129% in 2030. Natural gas is also predicted to rise from 18% to 21% in 2014 and by 108% to 146% in 2030. Total expenditures on energy rise due to the price increases from 15.5% to 33.5% in 2014 to 78.7% to 114.5% in 2030.

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3. Model: Multi-Region National (MRN-NEEM)

Group: CRA International

Authors: W. David Montgomery, Anne E. Smith

CRA International uses their MRN-NEEM model to estimate the effects of the Lieberman-Warner Climate Security Act. The MRN-NEEM is a "multi-region national" model that integrates a macroeconomic model of all economic sectors, consumers and income, consumption, investment, and trade with a model of the energy and non-energy sectors. It predicts Lieberman-Warner's effects on total emissions, price of the carbon allowances and energy, as well as the share of total power of various types of power generation.

The CRA model includes the low carbon fuel standards and the CCS provisions of S. 2191 as well integrating the provisions of H.R. 6. It models updated predicted oil costs using the *Annual Energy Outlook 2008*. The increased CAFE standards, renewable fuel standards and appliance efficiency mandated by H.R. 6 are already integrated into the baseline estimation.

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effect of banking on allowance price and found that banking increases the price in the short run and decreases the price in the long run. CRA estimates that banking reduces the present value of the costs of S. 2191 by $100 billion. W. David Montgomery, et al., "Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model," CRA International (April 2008)

This paper finds that the price of a carbon allowance starts at around \$50,[23] rises to around \$80 by 2030 and to \$190 by 2050. The CRA study also tests the effect of not allowing firms to borrow against future allowances. Without the banking, the price of an allowance remains lower than under the banking scenario until 2040, when they rise sharply due to the high abatement costs that firms would incur within the next twenty years; therefore, firms prefer to be net borrowers of allowances in the short run. The CRA study estimates that allowing the banking of allowances reduces the present discounted costs of S. 2191 by \$100 billion.

The model predicts that S. 2191 would cause GDP to fall by 1.9% in 2015. The effects of S. 2191 are mitigated from 2025 to 2035 due to costs of the CAFE standards already in place in the baseline. However, by 2050 GDP falls by nearly 3.5% because caps in that year mandate near-zero emissions. The present discounted cost of S. 2191 is estimated to be \$5.3 trillion by 2050.

The cost per household is estimated to be over \$2,000 (or 4.5% of household income) in 2015 falling to just above \$1,000 (2% of household income) in 2025 and rising again to \$2,000 by 2050. The CRA study models a yearly household income of \$50,000 when modeling the household cost amounts. CRA also estimates the loss in employment to be nearly 4 million jobs in 2015 and over 7 million by 2050.

The prices of motor fuel, natural gas and electricity rise due to the allowances. In 2015, electricity and natural gas prices are around 15% above the baseline estimate and motor fuel is over 140% higher. By 2050, motor fuel and natural gas are around 90% higher than the baseline and electricity is around 60% higher

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4. Model: Applied Dynamic Analysis of the Global Economy (ADAGE) and Intertemporal General Equilibrium Model (IGEM)

Group: Environmental Protection Agency

In this study, the EPA, at the request Senators Joseph Lieberman and John Warner, estimated the impact of S. 2191 on GHG emissions, the price of energy and the resulting impacts on other economic indicators. The EPA uses two models, ADAGE and

[23] Denominated in 2007 dollars.

IGEM,[24] to estimate three baseline scenarios and seven scenarios that embody various technologies, costs and availabilities. Specifically, the EPA tests the sensitivity of estimates by constraining the growth of technology like nuclear, biomass and carbon capture and storage (CCS) by assuming no international actions that go beyond what is required by the Kyoto Protocol and the availability of offsets. All cases allow for the banking of allowances and base future oil prices from the Annual Energy Outlook 2006. The study does not, however, include other measures that would reduce GHG emissions, such as H.R. 6.

The price of a carbon allowance under the assumptions of its "core" S. 2191 scenario is $29[25] in 2015 and increases to $159 in 2050, as estimated by ADAGE, and $40 in 2015, increasing to $220 in 2050, as estimated by IGEM. The scenario in which no offsets are available estimates the highest prices of $77 in 2015 and $425 in 2050. The "high technology" S. 2191 case estimates the lowest prices at $22 in 2015 rising to $121 in 2050.

The increased cost of energy lowers GDP by 0.18% in 2010, 0.9% in 2030 and 2.37% in 2050 according to ADAGE predictions of the baseline versus the core S. 2191 scenario. IGEM predicts more dire consequences to GDP, showing a loss of 0.94% in 2010, 3.76% in 2030 and 6.9% in 2050.[26] ADAGE predicts losses to total U.S. consumption of 0.43% in 2020 and 2.10% in 2050. IGEM predicts even larger losses of 0.66% in 2020 and 3.26% in 2050

According to ADAGE, households are estimated to lose about $446 in consumption or 0.43% of the baseline estimate in 2015. This number increases to $3,984 in 2050 or 3.26% less than the baseline household consumption. The price of a gallon of gasoline in 2030 is estimated to be $3.11. These estimates of future oil prices do no take into account interruptions in supply or temporary changes in the price and only represent the expected cost changes due to the law. Electricity prices will rise over the forecast period from the 2005 price by nearly 20% in 2015, 30% in 2030 and then fall back to 20% over the 2005 level in 2050.

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[24] Applied Dynamic Analysis of the Global Economy (ADAGE) and Intertemporal General Equilibrium Model (IGEM).
[25] Denominated in 2005 dollars.
[26] The elasticity of the supply labor is higher for IGEM than for ADAGE, thus the GDP losses are larger for IGEM.

5. Model: National Energy Modeling System (NEMS)

Group: Energy Information Administration (EIA)

The EIA, an agency of the Department of Energy, examines the effects of S. 2191 on energy prices and the economy at the request of several senators. The EIA uses the National Energy Modeling System (NEMS) for its forecasts. The model provides a baseline which includes H.R. 6, the Energy Independence and Security Act of 2007, estimates of voluntary technology adaptation provided by the EPA and forecasts of prices from the Annual Energy Outlook (AEO) 2008.

The S. 2191 "core" scenario models the effects of the cap and trade system for Group I GHGs and the bonus credit for carbon capture and storage (CCS) as well as other features of S. 2191. The EIA also forecasts using five other scenarios in which there are no international offsets available, high costs for electricity generating facilities, limited alternatives to coal power, and both limited alternatives to coal and no international offsets.

The EIA study predicts that the price of a carbon allowance will be $30[27] in 2020 and $61 in 2030 under the core scenario assumptions. The highest estimated price is found in the strictest case – limited alternatives and no international offsets – is $76 in 2020 and $85 in 2030.

6. Model: Global Insight

Group: The Heritage Center for Data Analysis (CDA)

Authors: William W. Beach, David W. Kreutzer, Ben Lieberman, and Nicolas D. Loris

The CDA examines the Lieberman-Warner Climate Security Act using a model developed by Global Insights. This study estimates a baseline that incorporates important elements of previously enacted energy legislation[28] and features of S. 2191. The main feature of S. 2191 that is modeled is the cap on CO2 emissions. The paper does not model the effect of the law on all of the GHG gases, only CO2[29] is considered; nor does it

[27] Denominated in 2006 dollars.

[28] Such as the higher CAFE standards mandated in H.R. 6.

[29] The estimates of the price of an allowance (and all resulting effects on GDP and prices of energy) are sensitive to the assumption that there is no banking of allowances. A study conducted by CRA International

model the effect of banking of allowances,[30] both of which are features of S. 2191.

The CDA models two different scenarios that might occur with S. 2191. In both of theses scenarios nuclear power is constrained to never be more than the base case, reflecting the difficulty in expanding production. In what is called the "generous" case, key technologies such as carbon capture and storage (CCS) are ready to be deployed when it becomes cost effective to use them. In the "reasonable" scenario, those key technologies do not exist within the twenty-year forecast.

The price of a carbon allowance is $49 in both the generous and reasonable forecasts in 2015. By 2030, the price rises to $68 in the generous model and $88 in the reasonable model. The generous forecast predicts that GDP will be 0.55% lower than the baseline in 2016 and 2030, while the reasonable forecast predicts GDP will be 1.41% lower in 2016 and 2.17% lower in 2030. Due to lower GDP, the economy has 166,000 fewer jobs than the baseline estimate in 2016 and 461,000 fewer jobs in 2030 according to the generous assumptions. The reasonable forecast predicts 855,000 fewer jobs than the baseline in 2016 and 431,000 fewer jobs in 2030. In 2016, personal consumption is predicted to fall by 0.89% under the generous assumptions and 1.61% in the reasonable forecast. By 2030, the predicted loss to personal consumption has been mitigated somewhat and is estimated to be 0.48% under the generous assumptions and 0.93% under the reasonable assumptions.

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7. Model: NEMS

Group: Clean Air Task Force (CATF)

Author: Jonathan Banks

The CATF uses the National Energy Modeling System (NEMS) the effects of S. 2191 on the economy and energy production. CATF assumes that technology improves

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tests the effect of banking on allowance price and finds that banking increases the price in the short run and decreases it in the long run. CRA estimates that banking reduces the present value of the costs of S. 2191 by $100 billion. Montgomery, W. David, et al., "Economic Analysis of the Lieberman-Warner Climate Security Act of 2007 Using CRA's MRN-NEEM Model," CRA International (April 2008).

[30] The estimates of the model are also sensitive to the number of different GHGs covered. Metcalf et al. find that by extending policy to cover more GHGs, the same reduction in total emissions can be achieved at a lower cost because abatement is less expensive for small amounts of reductions for many different gases. Metcalf, Gilber E., et al., "Analysis of U.S. Greenhouse Gas Tax Proposals," NBER Working Paper (April 2008).

according to the Energy Information Administration's "best available technology," and that the deployment of biomass power will be constrained. The features of S. 2191 that the CATF models are unlimited banking of allowances and the revenue from the auction of allowances will be used to produce a tax credit for carbon capture and storage. The CATF did not incorporate the new low carbon fuel efficiency standards, the Carbon Market Efficiency Board or limits on the future sources of power like nuclear or wind.

The study finds that the price of a carbon allowance starts at just over $15[31] in 2015 and rises to $45 in 2030 as the number of carbon allowances created falls. According to the study, GDP falls by 0.7% in 2030, which places the economy just four months behind the business as usual case. Per capita GDP falls by 0.9% from the reference case by 2030.

The CATF study also claims that even though the price of electricity rises, real spending on electricity falls from 2007 to 2030 due to improvements in end-use efficiency. Similarly, the price of natural gas rises, but real yearly expenditures on natural gas increases by only a dollar from 2007 to 2030. CATF also estimates that the cost of carbon allowances is almost completely passed through to the consumer, raising the price of gasoline by roughly $0.10 for every $10 per ton of CO2.

While other studies show that natural gas power generation increases until the point at which CCS becomes economic, this study shows that the subsidies for CCS cause it to enter earlier, and thus the price of natural gas does not have to rise as much as it would be expected to otherwise. However, the study does note that if either CCS or nuclear power is not allowed to expand for political or technological reasons, then natural gas will fill in the gap that coal-burning plants leave. The study does not predict that coal without CCS will be removed from the market by 2030 and still represents around 150 gigawatts of power supply.

Other proposals

S. 1766

The Bingaman-Specter Low Carbon Economy Act creates a cap and trade system for greenhouse gases similar to the Lieberman-Warner Act. S. 1766 was introduced to

[31] Denominated in 2004 dollars.

the Senate for comment in June 2007 and was subsequently sent to the Committee on Environment and Public Works. S. 1766 creates allowances that permit total covered emissions to be 6600 mmt in 2015. The government would lower the amount of allowances created until 2050, when the total allowances sold reduces emissions to 60% of 1990 levels (1927 mmt of CO2-e). As the number of allowances auctioned is lowered, the price of an allowance will rise. Many industries fear that abatement will be very costly and so the only option will be to emit and purchase allowances, which will cause the price of an allowance to be very high. To allay those fears, S. 1766 comes with a "release valve" called a Technology Accelerator Payment (TAP), which essentially is an upper limit on a price of carbon allowances.[32] Regulated entities can always meet their obligation by paying the TAP price, which is set at $12 in 2012 and grows at 5% per year in real terms. Because of this, the price of an auction will never exceed the TAP price. Under S. 1766, a percentage of allowances, which declines over time, is given away to regulated entities and there are also bonuses allotted for reducing GHGs from non-covered emissions and subsidies for carbon capture and storage.

The EIA uses the National Energy Modeling System (NEMS) to estimate the economic and environmental impact of S. 1766. The EIA estimates two reference cases. In both cases the EIA uses the forecasts from the AEO2007. However in one case they estimate the effects of the law using more optimistic assumptions on the availability of technology. The major features of S. 1766 that the EIA tests are the cap and trade limits, the TAP price, and bonus credits for CCS and non-energy abatement. For sensitivity, the EIA tests a scenario in which the CCS bonus is only half of what S. 1766 uses, a scenario with the optimistic technology assumptions, a scenario with supporting environmental policies like H.R. 6, a scenario with both optimistic technology assumptions supporting policies, and a scenario with limited alternatives to coal.

In each scenario, the TAP program is activated by 2030 and the price of an allowance does not rise above the TAP price for that year. Only in the "high technology" case in 2020 does the EIA predict that the price of an allowance is lower than the TAP price. Because of the TAP, total emissions in 2020 and 2030 are expected to exceed the

[32] If the price of an allowance ever rises above the TAP price, then the cap and trade system becomes essentially a tax on carbon emissions.

total covered emissions. In all of the cases except limited alternatives to coal, in 2015 GDP is higher with S. 1766 than the predicted baseline. By 2030, most scenarios are nearly equivalent to the baseline, but the core S. 1766 GDP is around 0.05% below the baseline and the limited alternative scenario predicts GDP will be 0.25% below baseline. As higher energy costs raise prices across the economy, real consumption falls by about 0.1% from the baseline in 2030 in the core scenario and by 0.2% in the limited alternatives scenario.

The cost of the allowances is passed forward into higher prices for gasoline, natural gas and electricity. In 2020, gasoline prices are predicted to be 0.06% higher than baseline, natural gas prices are predicted to be 0.7% higher, and electricity prices are predicted to be 0.5% higher. By 2030, gasoline and natural gas are predicted to be 0.8% higher and electricity is predicted to be 0.085% higher. The limited alternatives scenario predicts a small (less than .01 percentage points) increase in the prices of these goods.

Carbon Tax Proposals

Metcalf et al. (2008) employ MIT's Emission Prediction and Policy Analysis (EPPA) to estimate the effects of the carbon taxes on CO2 emissions, welfare costs, prices of consumer goods, tax revenues, and the effects on each income decile. Each tax proposal varies in the level of the tax and the way in which the tax grows-or remains constant- over time. The estimated costs to consumer welfare vary with each plan, from a nearly 1% gain under the least stringent plan to a 2% loss under the most stringent. Using information from the Consumer Expenditure Survey, the authors show that the carbon tax is regressive, but a lump sum per capita return of tax revenues is progressive. Each proposal considered taxes only carbon, however, if the taxes are extended to cover all greenhouse gases (GHGs) there are significant reductions in the lost consumer welfare. The authors also make comparisons between the tax plans and comparable "cap and trade" proposals and find there is little difference.

The three different plans analyzed are named for their main proponents in Congress, Dingell[33], Larson[34], and Stark-McDermott[35]. The Dingell Bill proposes a \$13.64 tax per ton of CO2 emitted along with a separate tax on gasoline of \$0.50; neither

[33] Dingell proposal still in draft.
[34] H.R. 3416; America's Energy Security Trust Fund Act of 2007
[35] H.R. 2069; Save Our Climate Act of 2007

tax changes over time[36]. The Larson Bill has an initial tax rate of \$19.96 that grows in real terms of 10% per year. The Stark Bill has an initial rate of \$10 that grows in nominal terms of \$10 annually. Each bill has its own plan for using the tax revenues.

Metcalf et al (2008) predicts the level GHG emissions over time[37] for each plan. The Dingell Bill is the least stringent plan and as such has the smallest effect on total emissions. The plan keeps total emissions at current levels until 2025 when emissions begin increasing at a rate comparable to the "business as usual" reference scenario. In 2050, the plan reduces emissions to 12 billion metric tons (bmt) per year from 13.5 bmt in the reference scenario. The Stark Bill manages to keep total emissions constant at today's levels of 8 bmt per year by 25%. The Larson Bill's relatively high tax rate reduces emissions to 4 bmt per year or roughly half of the current emission levels and 40% of the reference emission levels.

The EPPA model predicts the welfare costs of each plan. These costs include changes in market consumption as well as effects on leisure. The aggregate present discounted welfare change for the Dingell plan is a 0.01% gain in welfare due to the EPPA model's assumption that other countries will take steps to reduce emissions that in effect lower oil prices. The Stark plan has a slight loss to welfare of 0.03%. The Larson plan has the largest effect of a 1.2% reduction present discounted aggregate welfare.

The authors also model the tax plans covering non-CO2 GHGs. Since initial abatement for any gas is easier than subsequent reductions, extending the tax plan to cover all GHG can result in significant decrease in the tax rate. In fact, when more GHG are included the tax rate required to get to the same reduction in total emissions as under carbon-only tax falls under each plan. The Larson plan's initial tax rate could be reduced to \$13.30 per metric ton of CO2 emitted, the Stark plan's initial tax rate could be reduced to \$1.50 and the Dingell plan's initial rate could be reduced to \$12.80. Lowering the tax rate also reduces the welfare costs of each plan. The net present value of the aggregate welfare costs is reduced from 0.3% to 0.11%.

The tax revenue from each tax plan is substantial and can be returned to consumers in such a way as to mitigate and even reverse the regressive nature of the

[36] All dollar denominated in 2005 dollars

[37] Total GHG emissions includes the amount of CO2 emitted plus all other GHG weighted by their potential effect on global warming.

carbon tax. In 2015, the potential tax revenues from the plans are \$88, \$69 and \$126 billion per year from the Dingell, Stark and Larson plans, respectively. These tax revenues could account for 4% of total Federal tax revenue under the Stark plan and up to 7% under the Larson plan. As the tax rate in the Stark and Larson plans rises over time, revenues increase substantially; for the Larson plan in 2050 the carbon tax revenues would account for 21% of Federal tax revenue.

Using EPPA predictions on increases in prices on electricity, gasoline and other consumer goods of a generic \$15 tax per ton of CO2 emitted and information from the Consumer Expenditure Survey, the carbon tax is found to be regressive, but the level of its regressivity depends on a number of key assumptions. The first assumption is that consumers do not change behavior. If the full amount of the tax is shifted onto the consumer, then the poorest 10% of the population faces a 3.7% reduction in income while the richest 10% faces a 0.8% reduction in income. However, a per capita lump sum return of the tax revenue would actually result in making the carbon tax plan progressive. Another positive effect of a carbon tax is that the revenue can be used to reduce taxes on labor or capital and, thus, increase overall economic efficiency.

Conclusion

In this paper we have provided a brief summary of estimates of the greenhouse gases emissions' abatement costs with particular focus on households.

GDP reduction estimates vary widely from 0.3% to 3% drop below business-as-usual in 2015 and from 1% to 10% in 2050. The timeframes of new technology development and growth potential of existing clean sources of energy, availability of offsets (domestic, international), and permissibility of allowance banking are likely to account for most of these differences.

Consumption costs are affected by the same factors as GDP costs. Therefore, studies, which assume limited alternative sources of energy and/or limited offsets, usually predict smaller decreases in consumption than studies, which do not make such assumptions. (Estimated costs could differ by a factor of 2-3).

Despite the differences in estimates, our analysis strongly indicates the abatement costs could be around a 0.8%-1% of drop of consumption below the business-as-usual scenario. This is a conservative estimate; many studies project that costs are likely to be even higher. Given these estimates, we can conclude that the costs of mitigation are likely to be huge. According to Lucas (1990), a 1% permanent cost of consumption estimate is "something like 20 times the gain from eliminating post-war-sized business fluctuations. It is about 10 times the gain Arnold Harbenger (1954) once estimated from eliminating all product-market monopolies in the U.S."

Our research indicates that quantifying the costs of proposed policies dealing with climate change is a vital prerequisite to determining the appropriate course of action.

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Appendix

Summary of Assumptions of the Models

MIT: EPPA

- Banking of allowances
- No use of foreign allowances
- Four Cases
    - o No Domestic Offsets; No CCS Subsidy
    - o CCS Subsidy
    - o 15% Domestic Offsets
    - o 15% Domestic Offsets; CCS Subsidy

ACCF/NAM: NEMS

- No banking of allowances
- Caps on nuclear, sequestered coal-fired (IGCC) generation, sequestered natural gas-fired (NGCC), biomass and wind energy
- Estimated capital costs of new plant construction
- Two Cases
    - o Low Cost
        - Greater than 20% Offsets
        - *AEO 2008* Oil Prices
    - o High Cost
        - 15% to 20% Offsets
        - *AEO 2007* "High Profile Side Case" Oil Prices
        - Tighter caps on nuclear, sequestered coal-fired (IGCC) generation, sequestered natural gas-fired (NGCC), biomass and wind energy

CRA: MRN-NEEM

- Banking of allowances and one scenario of no banking
- *AEO 2008* natural gas prices, electricity demand growth, non-electric CO2 emissions

- Includes effects of H.R. 6
    - o CAFE standards
    - o Renewable Fuel Standard (RFS)
    - o Efficiency standards on power supplies and some appliances

EPA: ADAGE and IGEM

- Banking of allowances
- *AEO 2006*
- Three baseline estimations
    - o Normal
    - o High technology
    - o High technology and international actions
- Seven Cases

o Encapsulate different assumptions on prices, offset availability, technology growth, limitations on nuclear power and actions of other nations

CDA: Global Insight

- No banking of allowances
- Focus on CO2 only
- Two Cases
    - o Reasonable
        - § Assumes CCS does not develop with 20 year forecast
        - § No nuclear power beyond the base case
    - o Generous
        - § Assumes CCS is used for any coal-fired power plant built after 2018
        - § No nuclear power beyond the base case

EIA: NEMS

- Banking of allowances
- 6 Cases
    - o Baseline

- S. 2191 Core
- High Cost
- Limited Alternative to Coal
- No International Offsets
- Limited Alternatives and No International Offsets
- S. 1766

CATF: NEMS

- S. 2191
  - Banking of allowances
  - 30% Offsets
  - Bonuses and Subsidies for CCS
  - Subsidies for geological carbon sequestration (GCS), energy efficiency,
  - Money to offset electric and natural gas price increases
  - Constrains deployment of biomass
  - Unlimited nuclear growth
  - EIA's "Best Available Technology" Case

Estimating the Impact on Consumption Assumptions and Technical Details.

In this section we describe how to compute the balanced growth equivalent to the mitigation path consistent with Lieberman-Warner's. To find the balanced growth equivalent, we calculate the fraction consumption must decrease below the business-as-usual model in order to provide an individual the same level of utility/well-being as the abatement scenario.

Assumptions

In order to find that fraction we make the following five assumptions:

First, we assume a representative consumer with a constant elasticity of substitution (CES) utility function with a risk aversion parameter of 1 or 2. Consumers typically prefer minor changes in consumption over a longer period of time rather than having a large one-time change. The risk aversion parameter captures how much a consumer dislikes a volatile consumption stream. Values of this parameter around 1 and 2 are fairly standard in macroeconomic calibration exercises, and these figures are consistent with the assumptions made in Stern (2007) and Lucas (1990). Estimated costs differ only in the 4-th digit when we change risk aversion parameter. Thus, we present only one of the estimates in Table 2.

The second important assumption is that the rate of pure time preferences is about 3%-4%. The time preference reflects the consumer's desire, other things being equal, to consume today rather than tomorrow. This is consistent with Lucas (1989, 1990). If we follow Stern (2007) and assume this figure to be 0.1%, we are likely to get much higher estimates, though many authors argue that such choice of rate of time preference would be too low.[38]

Third, we need to account for growth in the U.S. population when computing social welfare. We assume that population grows at 0.6% annually taken from Paltsev et al. (2008).

Fourth, we must make assumptions concerning how consumption fluctuates in the intervening years between 2015, 2030 and 2050, since we only have cost estimates for those specific years. We use linear interpolation between the intervals so that decreases in consumption changes linearly between 2015 and 2030, and 2030 and 2050 to attain the estimated values presented in Table 2.

Finally, where the risk aversion parameter is 2, we assume that consumption per capita grows at 2% annually under business-as-usual scenario, following the Paltsev et al (2008) model). As we show in the technical appendix, when risk aversion coefficient is 1 we do not need to make any assumptions about consumption growth.[39] Since the estimates for the two risk-aversion numbers are virtually the same, this last assumption does not make a big impact on the results.

Technical Details

Consider an artificial economy with single infinitely lived consumer who has the same consumption stream as the aggregate consumption. We assume that the consumer maximizes discounted sum of utilities of the form:

[38] See Nordhaus (2007), Weitzman (2007) for the discussion on this issue.

[39] We do not even need the constant consumption growth assumption.

$$U = \sum_{t=0}^{T} \exp(-\rho t) u(C_t) N_t$$

Here $N_t = N_0 \exp(nt)$ is the population in period t, where n is the rate of population growth. Following current population growth projections (e.g., Paltsev et al (2008)), we can assume that population grows at about 0.6% to 0.8% (Assumption 3).

$u(c_t) = \frac{c^{1-\sigma}}{1-\sigma}$ is an instantaneous utility function, describing the utility derived from consumption at a given point in time. The assumption of this particular utility form is standard in macroeconomics and usually σ is assumed to be somewhere between 1 and 4, see e.g., Lucas (1990) (Assumption 1).

$\rho > 0$ is the rate of pure time preference. We assume it to be 3-4% (Assumption 2)

Also let under the business as usual scenario, i.e., without the costs of mitigation and the costs of climate change, consumption grows at the constant rate g. Thus, consumption would evolve as:

$$C_t = C_0 \exp(gt).$$

Following Paltsev et al. (2008), we assume that g=2% under business-as-usual scenario.[40] Given the recent economic situation, this number probably should be adjusted downward. (Assumption 5)

The Lieberman-Warner Act requires some abatement of GHG emissions which would result in decreases consumption by some fraction α_t. Table 2 provides estimates for α_t in 2015, 2030, and 2050. We use linear interpolation (Assumption 4 to approximate consumption drops in other years). Thus the consumption path under Lieberman-Warner or a similar policy becomes:

$$C_t^{LW} = C_0 \exp(gt)(1-\alpha_t).$$

Our task is to compute constant growth equivalent to this path, i.e., to compute λ such that if consumption declines by fraction λ below the business-as-usual path, then the consumer would get the same utility as under the LW path above: i.e., $C_t^{*LW} = C_0 \exp(gt)(1-\lambda)$ would bring the same utility as $C_t^{LW} = C_0 \exp(gt)(1-\alpha_t)$.

[40] Note that we mean consumption per capita.

This means that:

$$U(LW) = U(LW^*) \Leftrightarrow \sum_{t=0}^{T} \exp(-\rho t) u(C_t^{LW}) N_t = \sum_{t=0}^{T} \exp(-\rho t) u(C_t^{LW^*}) N_t$$

Substitution definitions of C_t^{LW} and $C_t^{LW^*}$ one gets that λ should solve:

$$\sum_{t=0}^{T} \exp(-\rho t) \frac{(C_0 \exp(gt)(1-\alpha_t))^{1-\sigma}}{1-\sigma} N_0 \exp(nt) = \sum_{t=0}^{T} \exp(-\rho t) \frac{(C_0 \exp(gt)(1-\gamma))^{1-\sigma}}{1-\sigma} N_0 \exp(nt)$$

or equivalently:

$$\sum_{t=0}^{T} q^t (1-\alpha_t)^{1-\sigma} = \sum_{t=0}^{T} q^t (1-\lambda)^{1-\sigma}$$

where $q = \exp(n + (1-\sigma)g - \rho)$. Thus, we can find the necessary drop in consumption λ from the following equation:

$$(1-\lambda)^{1-\sigma} = \frac{\sum_{t=0}^{T} q^t (1-\alpha_t)^{1-\sigma}}{\sum_{t=0}^{T} q^t}$$

This is the equation we use to compute the estimates of consumption drops. Since α_t are given only at 2015, 2030 and 2050, we use linear interpolation to infer the value of consumption drops in other years, i.e., we assume that in other years α_t changes linearly between known values in years 2015, 2030, and 2050.

There is slight disadvantage to the approach above. We need to make an assumption about the growth rate of consumption in the business as usual scenario. It appears that in a particular case we can overcome this problem.

Assume that the instantaneous utility function is logarithmic. This approach has the advantage that now we need not make specific assumptions about the path of consumption under the business-as-usual scenario. As the derivation below shows, under the log specification, estimated growth equivalent costs of mitigation will not depend on the path of consumption under the business-as-usual scenario. Yet the disadvantage is that some economists would argue that $\sigma = 1$ may be a bit too low.[41]

In this case constant (in percentage terms) drop in consumption λ would solve:

[41] Stern (2007) assume $\sigma = 1$, while Lucas (1990) sets it to 2. We consider both values.

$$\sum_{t=0}^{T} \exp(-\rho t) \log[C_t(1-\alpha_t)] N_0 \exp(nt) = \sum_{t=0}^{T} \exp(-\rho t) \log[C_t(1-\lambda)] N_0 \exp(nt)$$

Note that $\log C_t$ cancels from both sides of the equation above, hence λ will satisfy.

$$\sum_{t=0}^{T} \exp((n-\rho)t) \log(1-\alpha_t) = \sum_{t=0}^{T} \exp((n-\rho)t) \log(1-\lambda)$$

Thus λ solves:

$$\log(1-\lambda) = \frac{\sum_{t=0}^{T} \exp((n-\rho)t) \log(1-\alpha_t)}{\sum_{t=0}^{T} \exp((n-\rho)t)}$$

Using the outlined method for each of the scenarios in Table 2, we computed constant-over-time loss in consumption equivalent to estimated losses in consumption reported by Table 2. This constant loss is to be incurred every year starting today (2008) and going into the future up to 2050 or 2030. We stop our calculations at those time horizons because the studies do not model impacts of abatement on consumption beyond that timeframe.

However, most studies show that over time, consumption would drop more and more below its no-abatement level. In this regard, our estimate provides a lower bound. Also under a rate of time preference around 3-4%, anything happening after 2050 is unlikely to have any sizeable impact on our figures. For the studies which stopped at 2030, we compute two estimates: one for the horizon up to 2030, the other for the horizon up to 2050 with the assumption that damages between 2050 and 2030 are the same as the last available estimate, the one in 2030. We see that in this case, the estimate of the costs of mitigation will be even higher.

Text of the Program

```
% This program is used to compute the impact on consumption of the
% mitigation path consistent with Lieberman Warner Climate Security Act of
% 2007 S2191
n=0.006 % population growth
g=0.02 % consumption under BAU scenario
rho=0.04 % rate of pure time preference
gamma=2 % elasticity of substitution
q=exp(n+(1-gamma)*g-rho)
```

```
t0=2008;
T=2050;
for j=1:length(data(:,1))
alpha15=data(j,1);
alpha30=data(j,2);
alpha50=data(j,3);
for t=t0:T
   if t<=2015
      alpha(t-t0+1)=0+alpha15*(t-t0)/(2015-t0);
   else
      if t<=2030
         alpha(t-t0+1)=alpha15+(alpha30-alpha15)*(t-2015)/(2030-2015);
      else
         alpha(t-t0+1)=alpha30+(alpha50-alpha30)*(t-2030)/(2050-2030);
      end
   end
end
SA=0;
S=0;
for t=t0:T
   SA=SA+(q^(t-t0))*((1-alpha(t-t0+1))^(1-gamma));
   S=S+(q^(t-t0));
end
Percent(j)=100-(SA/S)^(1/(1-gamma))*100
%log drop
ql=exp(n-rho);
SAl=0;
Sl=0;
for t=t0:T
   SAl=SAl+(q^(t-t0))*log(1-alpha(t-t0+1));
   Sl=Sl+(q^(t-t0));
end
Percentl(j)=100-exp(SAl/Sl)*100
End
```

Tables

Table 7a: Change in Index of Electricity Gas Price (Index, 2005=1)

Group	Model	Scenario	Index 2015	Index 2030	Index 2050
MIT	EPPA	No Offsets, No CSS Subsidy	1.61	1.81	1.61
		15% Offsets	1.56	1.79	1.6
		CSS Subsidy	1.6	1.57	1.61
		15% Offsets, CSS Subsidy	1.55	1.57	1.61
ACCF/NAM*‡	NEMS	Low Cost	1.16	2.24	NA
		High Cost	1.17	2.54	NA
EPA**	ADAGE	S. 2191	1.1	1.3	1.2
	IGEM		NA	NA	NA
EAI**‡	NEMS	S. 2191 Core	1.02	1.1	NA
		S. 2191 Limited Alternative/No International Offsets	1.23	1.63	NA
CATF•	NEMS	S. 2191	NA	1.07	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020.
‡ Index constructed by using the EIA reported price of residential electricity in 2006 as 8.91 cents per kwh in 2006 dollars.

Table 8a: Change in Index of Gasoline Price (Index, 2005=1)

Group	Model	Scenario	Index 2015	Index 2030	Index 2050
MIT	EPPA	No Offsets, No CSS Subsidy	1.28	1.4	1.21
		15% Offsets	1.29	1.45	1.23
		CSS Subsidy	1.28	1.4	1.21
		15% Offsets, CSS Subsidy	1.29	1.45	0.12
ACCF/NAM*‡	NEMS	Low Cost	0.98	1.66	NA
		High Cost	1.3	2.3	NA
EPA**	ADAGE	S. 2191	NA	1.33	1.66
	IGEM		NA	NA	NA
EAI**‡	NEMS	S. 2191 Core	1.07	1.19	NA
		S. 2191 Limited Alternative/No International Offsets	1.18	1.44	NA
CATF•	NEMS	S. 2191	0.91	1.05	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020.
‡ Index constructed by using the EPA reported price of a gallon of gasoline in 2005 as $2.35 in 2005 dollars.

Table 9a: Change in Index of Natural Gas Price (Index, 2005=1)

Group	Model	Scenario	Index 2015	Index 2030	Index 2050
MIT	EPPA	No Offsets, No CSS Subsidy	1.14	1.97	1.87
		15% Offsets	1.15	2.12	1.98
		CSS Subsidy	1.13	1.57	1.65
		15% Offsets, CSS Subsidy	1.15	1.64	1.77
ACCF/NAM*‡	NEMS	Low Cost	1.63	3.33	NA
		High Cost	1.67	3.94	NA
EAI**‡	NEMS	S. 2191 Core	1.74	2.18	NA
		S. 2191 Limited Alternative/No International Offsets	2.28	3.24	NA
CATF•	NEMS	S. 2191	NA	1.03	NA

* ACCF/NAM reports in the year 2014.
**EIA reports in the year 2020
‡ Index constructed by using the EPA reported price of a tcf of natural gas in 2005 as $7.51 in 2005 dollars.
• Index constructed by using the CATF reported price of natural gas per MMBTU in 2006 as $13.80 in 2006 dollars.

Constructing the Index

Models estimate the price changes on gasoline, natural gas and electricity in one of two ways: one, the model may estimate a baseline price and the price under S. 2191, so that a percentage change in price caused by S. 2191 can be evaluated; two, the model may estimate a price and create an index based on a base price-typically the 2005 price. This allows readers to gauge the how prices will be in the future compared to today.

These two kinds of estimates are not readily comparable without additional information. Since the models that present price change estimates as an index do not report the estimate of the future baseline price, it is not possible to calculate the percent change from the baseline caused by S. 2191. However, when studies report a predicted future price an index can be constructed that does allow direct comparison.

For example, the EIA reports that the price of a gallon of gas in 2030 will be $2.95 in 2006 dollars. The EPA reports that the 2005 price of gasoline was $2.34 in 2005 dollars. Adjusting the EIA predicted price for inflation using the CPI, the predicted 2030 price is $2.88. Dividing the inflation adjusted EIA predicted price by the EPA reported price of gasoline yields 1.23, meaning there will be a 23% increase in the price of gasoline from 2005 to 2030 under S. 2191.

Table 3. Logit Regression of Cloture vote for S. 3036 using Longstreth's Health Variables

	Independent Variables	[1] Coefficients	[2] Marginal Effects
Political Variables	ADA Score	0.1309 ***	0.032166
		0.0376	0.00907
	Contributions from Sierra Club (in thousands)	-0.1595 **	-0.0391998
		0.0740	0.01825
	Sierra Club Members per 1 Million People	0.0004	0.0000964
		0.0008	0.00019
Economic Variables	Percent of State Power from Nuclear Energy	0.0547	0.0134563
		0.0498	0.01234
	Percent of State Power from Renewable Energy	0.0437	0.0107302
		0.0401	0.00994
	Median Household Income (in thousands)	0.0853	0.0209637
		0.2078	0.05114
	Predicted Household Cost (in thousands)	-1.2528	-0.3079175
		0.9134	0.22818
Health Variables (Longstreth)	Heat-Related Illness	-0.0418	-0.0102549
		2.1617	0.52922
	Heat Waves	-2.8457	-0.4929405
		1.9627	0.2062
	Ozone Non-Attainment Areas	0.0838	0.0205728
		1.6200	0.39734
	Algal Blooms	0.5239	0.1292246
		1.5732	0.38568
	Storms and Floods	1.0160	0.2485593
		2.1326	0.49655
	Hantavirus	-2.1322	-0.4356083
		1.8509	0.28041
	Arborvirus Encephalitis	-1.2107	-0.2892353
		1.8217	0.41024
	Malaria and Dengue Fever	4.1048	0.7187087
		3.1144	0.29635
	Constant	-5.5640	
		5.6061	
	Obs	100	
	Pseudo R squared	0.7377	

Notes:
Estimated standard errors are reported below the coefficient estimates
Asterisks imply statistically significant at the * .10 level; ** .05 level; *** .01
For indicator variables, marginal effect is calculated as a change from 0 to 1.

Table 4. Logit Regression of Cloture vote for S. 3036 using Alternative Specifications

	Independent Variables	[1] Coefficients	[2] Marginal Effects
Political Variables	**ADA Score**	0.1335154 ***	0.0270844
		0.0407978	0.00789
	Contributions from Sierra Club (in thousands)	-0.1455505 **	-0.0295258
		0.0722863	0.01532
	Sierra Club Members per 1 Million People	0.0019222	0.0003899
		0.001285	0.00025
Economic Variables	**Percent of State Power from Nuclear Energy**	0.0994659 *	0.0201773
		0.0522052	0.00978
	Percent of State Power from Renewable Energy	-0.0052417	-0.0010633
		0.0408348	0.0082
	Median Household Income (in thousands)	0.2949334	0.0598291
		0.4017053	0.0714
	Predicted Household Cost (in thousands)	-2.608623	-0.5291754
		1.912082	0.33299
Health Variables (Longstreth)	**Heat-Related Illness**	-2.613605	-0.3466399
		2.55507	0.17159
	Heat Waves	-1.521145	-0.2370506
		2.127044	0.28007
	Ozone Non-Attainment Areas	-1.117167	-0.2323109
		1.88762	0.36724
	Algal Blooms		
	Storms and Floods	-0.4313781	-0.0824983
		2.446124	0.43731
Health Variables (CDC)	**Hantavirus Cases Per 1 Million People**	-0.2074499 *	-0.0420825
		0.1248051	0.02504
	Arborvirus Encephalitis Cases Per 1 Million People	-0.9111839 *	-0.1848393
		0.5185856	0.11634
	Malaria Cases Per 1 Million People	-0.6386881	-0.1295619
		0.61629	0.101
	Skin Cancer Deaths Per 1 Million People	-0.4536385	-0.0920234
		2.253909	0.45591
	Coastline	-0.4518591	-0.090749
		1.961778	0.39583
	Constant	-0.5304299	
		7.958697	
	Obs	100	
	Pseudo R squared	0.7472	

Notes:
Estimated standard errors are reported below the coefficient estimates
Asterisks imply statistically significant at the * .10 level; ** .05 level; *** .01
For indicator variables, marginal effect is calculated as a change from 0 to 1.